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FARMERS' PESTICIDE USE DECISIONS AND ATTITUDES ON ALTERNATE CROP PROTECTION METHODS

RvR CONSULTANTS

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY
COUNCIL ON ENVIRONMENTAL QUALITY

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PREFACE

The study on "Farmers' Pesticide Use Decisions and Attitudes on Alternate Crop Protection Methods" was conducted by RvR Consultants as Project No. 53, under contract to the Council on Environmental Quality and the U. S. Environmental Protection Agency (Contract No. EQC 325). Dr. Warren R. Muir was Project Officer for the Council on Environmental Quality, and Dr. Jay Turim and Mr. Charles D. Reese represented the Environmental Protection Agency.

The study was initiated in July of 1973, and its information gathering phase was concluded in January of 1974. The program has been directed by Dr. Rosmarie von Rümker, Managing Partner, RvR Consultants, who also served as principal investigator. Mrs. Freda Horay, RvR Partner, served as project associate. She assisted in all phases of the study and handled the tabulation and processing of the results of a comprehensive survey of Iowa and Illinois farmers conducted in the project. Mr. L. E. Bailey, project associate, assisted in field work and led the team that conducted the personal farmer interviews in Iowa under Dr. von Rümker's direction.

Dr. J. C. Headley, Dr. R. L. Metcalf, Dr. W. H. Luckmann, Dr. H. J. Stockdale and Dr. D. W. Staniforth served as consultants to the project. Many other persons made valuable contributions, including 297 farmers in Iowa and Illinois who cooperated in providing answers to a comprehensive set of questions about their farming and crop protection practices and information sources.

The final report draft was submitted to the sponsoring agencies and to several independent reviewers. It has been reviewed by 18 experts affiliated with the Council on Environmental Quality, the U. S. Environmental Protection Agency, the U. S.

Department of Agriculture, the Federal/State Cooperative Extension Service, and several State Universities.

The authors gratefully acknowledge the project officers' guidance throughout the study, and the many constructive comments received from reviewers that were very helpful to the finalization of this report.

RvR CONSULTANTS

By Rosmarie v Rümker.
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10 July 1974

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I. SUMMARY AND RECOMMENDATIONS

A. Scope of the Study and Resources Employed.

Farmers' reasons for using pesticides, their knowledge of alternate crop protection methods, and their sources of information on both chemical and nonchemical crop protection methods were studied. The corn/soybean production system in the states of Iowa and Illinois was selected as a "study system" because (1) corn and soybeans are the two leading U. S. crops in terms of farm value; (2) the use of chemical pesticides on these crops is heavy and increasing; and (3) Iowa and Illinois are the two leading states in the production of corn and soybeans in the U. S.

Resources employed in this project included an outstanding panel of consultants; literature studies; the results of several previous surveys; and numerous field contacts with members of the federal/state agricultural research and extension system, state universities, state governments, the pesticide industry, and other knowledgeable persons. In addition, a field survey was conducted, involving about 300 farmers in Iowa and Illinois, each of whom provided replies to a question form that included 149 information items, grouped in four sections and 46 master questions. About 45,000 individual information items were processed, providing extensive information on the respondents' farming and crop protection practices and on their pesticide information sources.

B. Pesticide Use Patterns, Side Effects and Alternatives.

Chemical pesticides, especially herbicides and insecticides, are used extensively in the production of corn and soybeans in the midwest.

Herbicides are used by close to 100% of all corn and soybean growers in Iowa and Illinois, and close to 90% of the total acreage of these crops is treated with herbicides. The use of herbicides on corn and soybeans is more profitable and convenient to growers than the control of weeds by cultivating or other means. In spite of the availability and use of an array of effective herbicides, weeds still cause considerable yield losses, especially on soybeans. Growers are familiar with a number of alternatives to chemical weed control, but none of these are nearly as attractive as herbicides in regard to efficacy, convenience and profitability.

Among the three major pesticide uses studied, soybean herbicides are considered most essential by farmers. Almost one-quarter of the farmers interviewed stated that they would quit growing soybeans if no herbicides were available, while only 3-6% of them said they would not grow corn without herbicides or insecticides.

Three herbicides, i.e., atrazine on corn, and trifluralin and chloramben on soybeans, have been used more extensively than all others combined. Presence and persistence of atrazine residues in the soil and carryover to the next season have been reported, especially in Iowa. Trifluralin soil residues have also been found in some samples.

Weed populations in corn and soybeans are gradually changing; more difficult-to-control weeds are becoming more prevalent as those species that are easily controlled recede.

The cost of chemical herbicides has increased somewhat during the last five years, but this is not a major concern to growers because the prices of corn and soybeans have increased much more, especially during the last two years.

Insecticides were used on corn at an increasing rate during the 1960's. In 1969 and 1970, close to 70% of the total acreage in Illinois was treated. Since that time, the use rate has declined slightly. Until about 1970, chlorinated hydrocarbon insecticides (80-90% aldrin) were used in larger quantities than other products. The less persistent organic phosphate and carbamate insecticides have increasingly replaced chlorinated hydrocarbons during the last few years, especially in Illinois where the extension service has recommended against the use of chlorinated hydrocarbon insecticides for soil insect control since 1969. In addition, Illinois appears to have a more vigorous program of monitoring for pesticide residues and enforcing established tolerances in farm products. Iowa still recommends aldrin, heptachlor and chlordane for the control of soil insects.

Close to 6 million acres of corn in Illinois were treated with soil insecticides in recent years, primarily against corn rootworms. Entomologists estimate that only about 40% (2.5 million acres) of this acreage needed treatment. Concerning control of soil insects other than corn rootworms, it is estimated that of 4.5 - 5.0 million acres/year treated with chlorinated hydrocarbon insecticides in both states in recent years, at least 2.5 million acres did not need the treatment. However, diagnostic and predictive methods available to growers are not adequate, and it is often difficult for them to know whether or not to use an insecticide. Thus, from an overall standpoint, a substantial portion of the corn soil insecticide uses appear to be unnecessary or wasteful, while most growers consider their individual decisions to us a preventive treatment a necessary protection against possible yield losses.

Residues of aldrin, the most widely used soil insecticide, are widespread in Iowa and Illinois soils and have also been found in milk, meat, poultry, eggs, and soybeans produced in the area, as well as in wildlife, fish, rivers, lakes and streams. Residues of heptachlor and heptachlor epoxide were also found in a number of soil samples from Iowa and Illinois, but less frequently than aldrin and dieldrin. These findings are in line with the use patterns of these insecticides.

Several target insects including corn rootworms, seedcorn beetles and seedcorn maggots have developed resistance to chlorinated hydrocarbon insecticides.

Regarding alternatives, the effects of crop rotation on the occurrence of corn insects are recognized by most corn growers. However, crop rotation decisions are affected by many factors, most of them overriding crop protection considerations. Other non-chemical methods for the control of soil insects are currently being researched, but none of them are ready for field use. Better methods to diagnose and predict corn insect infestations are urgently needed to identify those areas and fields that really need treatment.

On midwestern soybeans, insecticides have been required only sporadically in the past. There are no soil insects requiring control, and foliar insects have been a problem only occasionally. An outbreak of green cloverworms, a foliage feeding insect, occurred in 1973. Iowa and Illinois issued somewhat divergent treatment recommendations, and producers and sellers of soybean insecticides, naturally enough, gave greater publicity to the Illinois version that recommended a lower treatment threshold than Iowa.

Experiences in other soybean areas of the U. S. indicate that injudicious use of insecticides on soybeans may result in progressive destruction of natural control factors, need for more chemical insect control, etc. An effective management program for soybean insects in the midwest is therefore most desirable at this time where regular use of insecticides on this crop has not yet begun.

Recommendations:

- -- *Promote development and use of better methods for diagnosis of corn soil insect problems and for predicting treatment needs in order to eliminate unnecessary pesticide uses.*
- -- *Promote development and implementation of insect management programs for corn and soybeans.*

C. Pesticide Information Flow Patterns.

Farmers in the midwest receive information on pesticides primarily from pesticide sellers, labels, and other farmers. University extension specialists, area extension agents and county agents (farm advisers) are regarded as very useful sources of information on pesticides by farmers. They are very effective communicators, considering their small numbers in relation to the large number of farmers they serve. However, these public servants are outnumbered by pesticide industry representatives and pesticide sellers by wide margins, and their messages reach only a small percentage of growers directly. Extension publications likewise do not reach a significant percentage of growers directly. Extension publications are also sent to news media including farm magazines, newspapers, radio and TV and are reproduced by these media in whole or in part, but this does not appreciably increase the information flow to farmers because farmers do not think highly of these media as sources of pesticide information and do not use them much for this purpose. The pesticide trade is by far the largest direct clientele for pesticide information from state universities and extension services outside of the university-extension system itself.

These pesticide information flow patterns developed during a period when the objectives of the pesticide trade were essentially in harmony with those of federal and state agencies. In the past, pesticide development and increased use of pesticides generally meant progress to both groups. Messages recommending reduced or no use of pesticides do not flow well through this system.

Many of the farmers interviewed expressed interest in receiving more specific, individualized crop protection advice. Some of this information is available from public sources, some of it would have to be adapted to local conditions. However, there are currently no effective, unbiased channels through which growers could receive such information regularly and in a timely fashion from the public agency originators of the information.

Recommendation:

-- *Promote development and use of unbiased channels of communication between public agencies that generate crop protection information and growers who need that information.*

D. Pesticide Information Messages.

Most farmers are businessmen who apply crop protection measures for economic reasons, i.e., to prevent yield losses that occur if pests would not be controlled. Most often, pesticides are the tools of choice because, based on the information available to farmers, they are more effective and convenient and, especially, more profitable than other alternatives.

Profit incentives will be far more effective than any others in prompting growers to adopt more judicious crop protection strategies. As businessmen, farmers are naturally interested in increasing or at least preserving the productivity of their assets, including the fertility of their land and the effectiveness of their tools, including crop protection tools.

There is increasing evidence that in the long run, only those crop protection strategies that are ecologically sound will also be economically sound. However, the fact that current crop protection decisions may entail hidden future costs is generally not known to farmers, and no effort is being made to bring it to their attention. Both farmers and those advising them on crop protection base their choices and their views on the profitability of available alternatives on comparisons between the cost of the treatment and the value of the crop yield loss to be prevented. Two important types of side effects are generally neglected.

Firstly, surprisingly little information is available on the interactions between different pesticides, and between pesticides and all other elements of crop production systems. For instance, chemical herbicides, insecticides, fungicides, and fertilizers are often applied to the same land year after year. Most of these chemicals remain in the upper 1-3 inches of the soil. Little is known about their routes and rates of degradation under field conditions, on their individual and collective effects on the soil microflora and microfauna, and on the long-term fertility of the topsoil.

Secondly, the past history of the use of pesticides teaches that the usefulness of most or all of these chemicals is gradually eroded by the development of resistance in the target pest(s), the selection of pest populations that are increasingly more difficult to control, the destruction of beneficial organisms, and other factors. No data are available on how current corn and soybean crop protection practices might affect the future profitability of these crops.

Information on these (and other) side effects that are currently largely disregarded would provide farmers and those advising them with a better basis for making ecologically and economically sound crop protection decisions.

Recommendations:

-- *Provide growers with more information on comparative advantages, disadvantages and costs of pesticides, and on treatment thresholds and other details regarding their most judicious use.*

-- *Promote more interdisciplinary studies on the present and future biological and economic effects of different crop protection strategies on the crop production systems of which they are a part.*

-- *Promote greater awareness of the fact that current pesticide uses may entail not only future adverse ecological effects, but also adverse economic effects on the user himself.*

E. Applicability of Findings to Other Crops and Areas.

This study has provided a detailed analysis of the pests and pesticide use patterns on corn and soybeans in Iowa and Illinois, and of the pesticide information sources, channels and messages that guide growers in making crop protection decisions. The extent of use of different pesticide information sources, their degree of usefulness as perceived by growers, and pesticide information flow patterns were quantified, and interrelationships, strengths and weaknesses within this system were identified.

Very few, if any similar studies have been reported thus far in which all of these factors were investigated, documented and evaluated in a comparable, holistic fashion for other crops, including the interrelations between major elements of the production system (e.g., land use patterns; farm sizes and number of farms; crop rotation patterns; commodity prices; pest infestations; pesticide costs, use practices, and side effects; alternatives to unilateral reliance on pesticides), and the sources and content of, and the delivery systems for information on crop protection and pesticides that growers use in making crop protection decisions. Thus, in the absence of similar studies on other crops for comparison, it is difficult to know to what extent the findings of this study can be extrapolated to other crops and areas. Different climates, soils, crop production and rotation systems, land use and farm size patterns, etc., generate different pest problems, crop protection needs and pesticide use patterns. Public agencies, universities, state legislatures, commodity organizations, etc. differ in their philosophies and approaches to crop protection and pesticides, and in the vigor of their pesticide monitoring and enforcement activities, if any. Very likely, different mixes of these factors produce somewhat different problems, needs and opportunities in other regions of the United States.

In addition to the important findings applicable to corn and soybeans in Iowa and Illinois (and, probably, to neighboring corn belt states), this project has provided a study approach, including methods for the identification and quantification of a number of critical parameters, that lends itself to the collection and analysis of similar information for other areas and other crops, and to further development and refinement.

Research successes in developing alternatives to sole reliance on chemical pesticides, in integrated pest management, and in other areas of crop protection will not improve agricultural production or environmental quality in and of themselves, but only if, and to the extent that they are implemented by growers. Growers' decisions and actions are based on the quantity and quality (as perceived by them) of the information available to them. Thus, knowledge of the sources, content and flow patterns of such information, and of the effects of the information system on the crop protection choices and practices resulting from it (as accumulated in this study), is an important prerequisite to efforts to improve the effectiveness and reduce the (monetary and ecological) costs of crop protection.

Recommendation:

-- *Promote similar, holistic studies for other crops and regions on farmers' crop protection information, and on the crop protection decisions and practices resulting from that information, with a view to determining where such information systems might need strengthening. Efficient transfer of the best available crop protection information to growers is an important element in assisting them to make economically and ecologically sound crop protection decisions.*

II. INTRODUCTION

Crop yield losses due to pests including insects, weeds, plant diseases, and other organisms reduce farming profits. Modern agricultural production techniques such as growing large, continuous stands of one crop, use of high yielding crop varieties, fertilizers, and other production inputs tend to increase potential crop losses due to pests and thus the incentive to prevent such losses. Since the advent of synthetic organic pesticides, farmers have increasingly relied on the use of chemicals for the protection of their crops.

Sole reliance on chemical pesticides has failed as a crop protection strategy in a number of instances because of the development of resistant pest strains, selection of increasingly resistant pest populations, destruction of natural control factors, outbreaks of secondary pests, and other adverse effects. The dvelopment of crop protection strategies alternative to sole reliance on chemical pesticides has therefore become necessary, and substantial research and development efforts are targeted toward this goal. However, these programs will not affect agricultural production or environmental quality unless and until they are reduced to practice at the grower level. This study was undertaken to obtain first-hand grassroots information on farmers' current pesticide use practices and on the pesticide information sources, channels and messages that guide them in their crop protection decisions, in particular, -

-- The basic factors motivating farmers to use pest control systems;

-- The extent and source of farmers' knowledge of alternative pest control systems, especially those not involving the use of chemical pesticides;

-- The factors influencing the decision of which control system to select; and,

-- where chemical pesticides are chosen as a control system, the factors influencing the decision of which particular chemical pesticide to use, and the factors influencing the farmers' determination of the manner, timing, and level in which it should be applied.

The study proceeded in five stages:

(1) Review of the pertinent literature;

(2) analysis of the use patterns of pesticides on major crops and selection of one or more major crop production systems for detailed analysis;

(3) in-depth analysis of the selected crop system or systems in terms of the framework set forth above;

(4) identification of wasteful and/or environmentally objectionable pesticide use patterns and the availability and practicality of alternatives;

(5) identification of factors or incentives that would prompt growers to adopt alternatives.

The corn/soybean production system in the midwest was selected as an appropriate "study system" for this investigation. Corn and soybeans are the two leading cash crops in the United States, and the two crops combined account for about 40% of the total harvested cropland acreage in the U. S. Large quantities of chemical pesticides, especially herbicides and insecticides, are used on these crops. The study was centered in the states of Iowa and Illinois, the two leading corn and soybean producing states in the nation.

The results are presented by way of an introductory discussion of the production of corn and soybeans in the study area, and the uses and costs of pesticides applied to these crops. Corn and soybean insects and weeds and their control are then discussed in four separate chapters. Corn insect control patterns were studied in the greatest detail because this is the area of greatest concern in regard to actual and potential wasteful uses of chemicals and undesirable side effects. Also, many farmers expressed interest in more specific, individualized advice on the control of insects, while they were generally more confident of their ability and competence to cope with weeds by the use of herbicides or otherwise.

Findings in regard to farmers' sources of information on pesticides are presented in terms of the four major elements involved in a communication process, i.e., originating sources or senders; channels through which the information is transmitted; receivers and their use of the information; and content of the information itself.

Literature references, and other resources and methods employed in the study are listed and described in the last two sections of the report, and in two appendices.

A summary of the findings of the study, and recommendations resulting therefrom were placed at the beginning of the report to highlight them.

III. PRODUCTION OF CORN AND SOYBEANS IN THE U. S. AND IN IOWA AND ILLINOIS

A. Past Developments, Future Trends.

In terms of farm value, corn and soybeans are the two leading crops in the United States. Corn also leads all other crops in total acreage, while soybeans are in fourth place in this regard, behind hay crops and wheat (U. S. Department of Agriculture, 1972a). In 1973, 71 million acres were planted to field corn, that is almost 25% of the total U. S. harvested cropland acreage, and almost 3% of the total land area of the 50 states.

Tables 1 and 2 summarize acreage, production and value of corn and soybeans in the United States for the 5-year period 1969 - 1973, and projections for 1980 and 1985. Worldwide as well as domestic demand for corn and soybeans have increased substantially during the last two years.

The corn acreage harvested for grain in the U. S. has varied between 54.6 million acres in 1969 and 64.0 million acres in 1971 (Table 1). 61.5 million acres of corn were harvested for grain in 1973. The corn acreage for grain production is expected to increase to 73.7 million acres by 1980, 75.5 million acres by 1985.

Corn yields per acre have generally been on the uptrend from 1969 to 1973, except for a dip in 1970, caused by the combined effects of a fungus disease, the southern corn leaf blight (*Helminthosporium maydis*), and drought in many of the corn producing regions in the United States. The U. S. Department of Agriculture projects further increases in corn yields, to about 110 bu./acre in 1980, and 120 bu./acre in 1985. These projections appear to be attainable; the average corn yields in Iowa and Illinois are already at or above 110 bu./acre today.

Table 1 : U. S. Corn Acreage, Production and Value, 1969 - 1985.

Year	1969	1970	1971	1972	1973[1/]	1980[2/]	1985[2/]
Acres planted, (000)[3/]	64,264	66,849	74,055	66,753	71,332	6/	6/
Acres harvested, (000)[4/]	54,574	57,358	64,047	57,289	61,479	73,700	75,500
Production							
- per harv.'d acre, bu.	85.9	72.4	88.1	96.9	92.4	109.5	120.0
- total, Million bu.	4,687	4,152	5,641	5,553	5,678	8,070	9,060
Av. price received by farmers, $/bu.	1.16	1.33	1.08	1.60	2.30[5/]	6/	6/
Value of production							
- per acre, $	99.64	96.29	95.15	155.04	212.52	6/	6/
- total, Million $	5,437	5,522	6,092	8,885	13,059	6/	6/

1/ Preliminary
2/ USDA forecasts
3/ For all purposes
4/ For grain
5/ USDA estimate
6/ Not available

Sources: U. S. Department of Agriculture, 1973c. Feed Situation, Fds-251, November. Economic Research Service.

U. S. Department of Agriculture. 1973a. American Agriculture, its Capacity to Produce. The Farm Index 12(12): 8-14,16

Table 2 : U. S. Soybean Acreage, Production and Value, 1969 - 1985.

Year	1969	1970	1971	1972	1973[1/]	1980[2/]	1985[2/]
Acres planted, (000)	42,198	43,332	43,176	46,700	57,000	4/	4/
Acres harvested, (000)	40,982	42,249	42,701	45,755	56,173	64,100	65,700
Production							
- per harv.'d acre, bu.	27.5	26.7	27.5	28.0	28.0	32.0	34.5
- total, Million bu.	1,126	1,127	1,176	1,283	1,575	2,051	2,267
Av. price received by farmers, $/bu.	2.35	2.85	3.03	4.75	5.00[3/]	4/	4/
Value of production							
- per acre, $	64.63	76.10	83.33	133.00	140.00	4/	4/
- total, Million $	2,647	3,212	3,563	6,094	7,875	4/	4/

[1/] Preliminary
[2/] USDA forecasts
[3/] USDA estimate
[4/] Not available

Sources: U. S. Department of Agriculture. 1973b. Fats and Oils Situation, FOS-270, November. Economic Research Service.

U. S. Department of Agriculture. 1973a. American Agriculture, its Capacity to Produce. The Farm Index 12(12): 8-14,16

Increased corn acreage and yields combined are expected to boost total corn production to above 9 billion bu./year by 1985, from the present level of around 5.6 billion bu./year that was achieved during 1971, 1972 and 1973.

The average price for corn received by farmers has more than doubled during the last two years, increasing the average value of production per acre by 123% between 1971 ($95.15/acre) and 1973 ($212.52/acre).

Recent developments in the production of soybeans are equally dramatic (Table 2). The soybean acreage harvested for beans in the U. S. varied between 41 and 46 million acres between 1969 and 1972. It jumped to 56 million acres in 1973 and is expected to reach 64.1 million acres by 1980, 65.7 million acres by 1985.

Soybean yields per acre have hovered around 27 to 28 bu./acre during the last 5 years, but the U. S. Department of Agriculture expects an increase to 32 bu./acre by 1980, 34.5 bu. per acre by 1985. Average soybean yields in Iowa and Illinois in 1972 were 35 - 36 bu./acre.

Increased soybean acreage and yields combined are expected to raise the total U. S. soybean production from 1.6 billion bu. in 1973 to 2.3 billion bu. by 1985.

The average price for soybeans received by farmers increased from $3.03/bu. in 1971 to $4.75/bu. in 1972, and to an estimated $5.00/bu. for the 1973 crop. As a result, the value of production per acre of soybeans increased by almost 70% from 1971 ($83.33/acre) to 1973 ($140.00/acre).

The regional distribution of the corn and soybean acreage throughout the United States is shown in Figures 1 and 2. Iowa and Illinois rank first and second in the nation in the production of both corn and soybeans, Iowa being the leading corn state, Illinois the leading soybean state.

Fig. 1 : **CORN HARVESTED FOR ALL PURPOSES, 1964**

(Latest map available; geographical distribution still representative.)

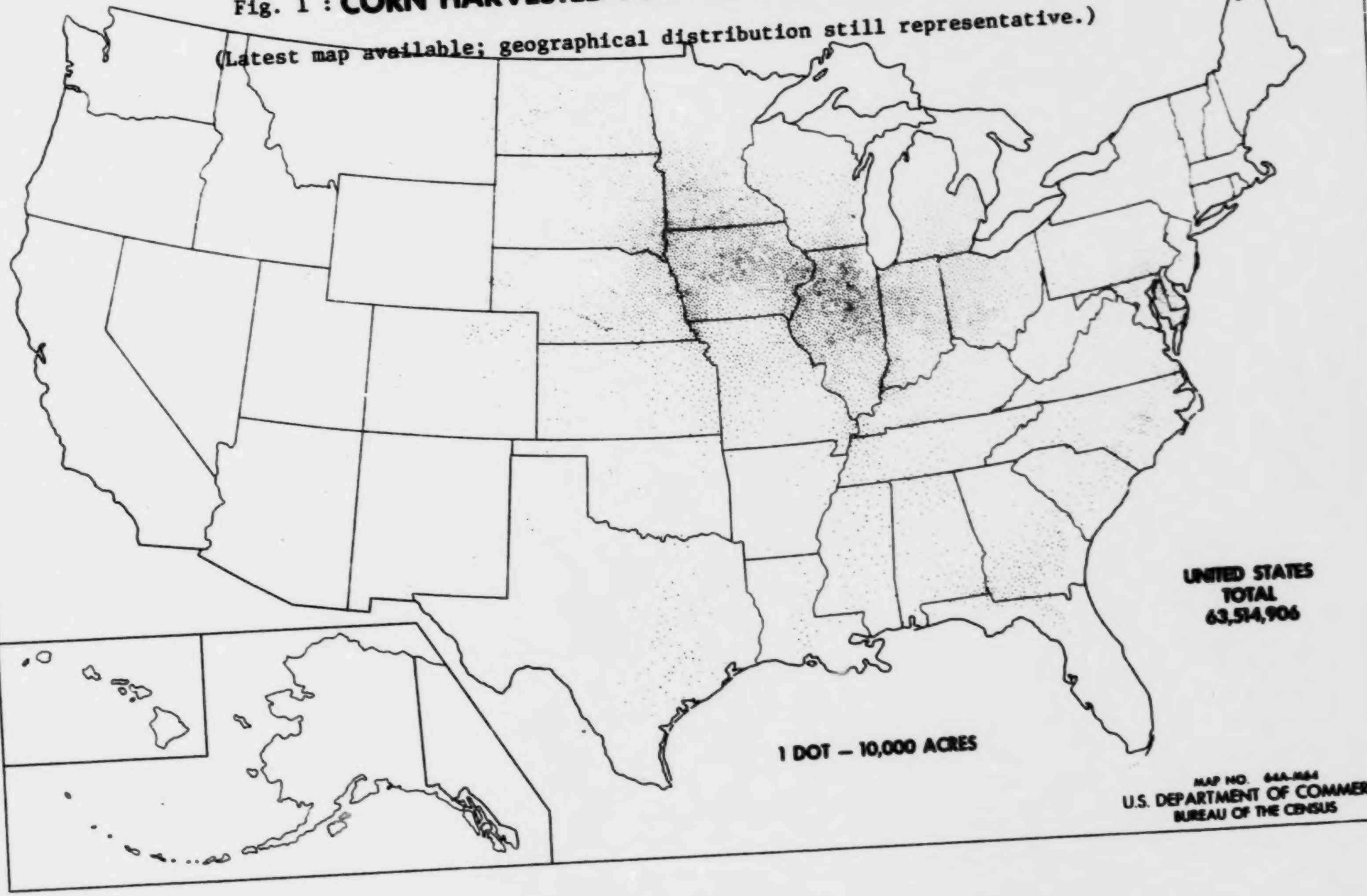

Fig. 2 : **SOYBEANS HARVESTED FOR ALL PURPOSES, 1964**

(Latest map available; geographical distribution still representative.)

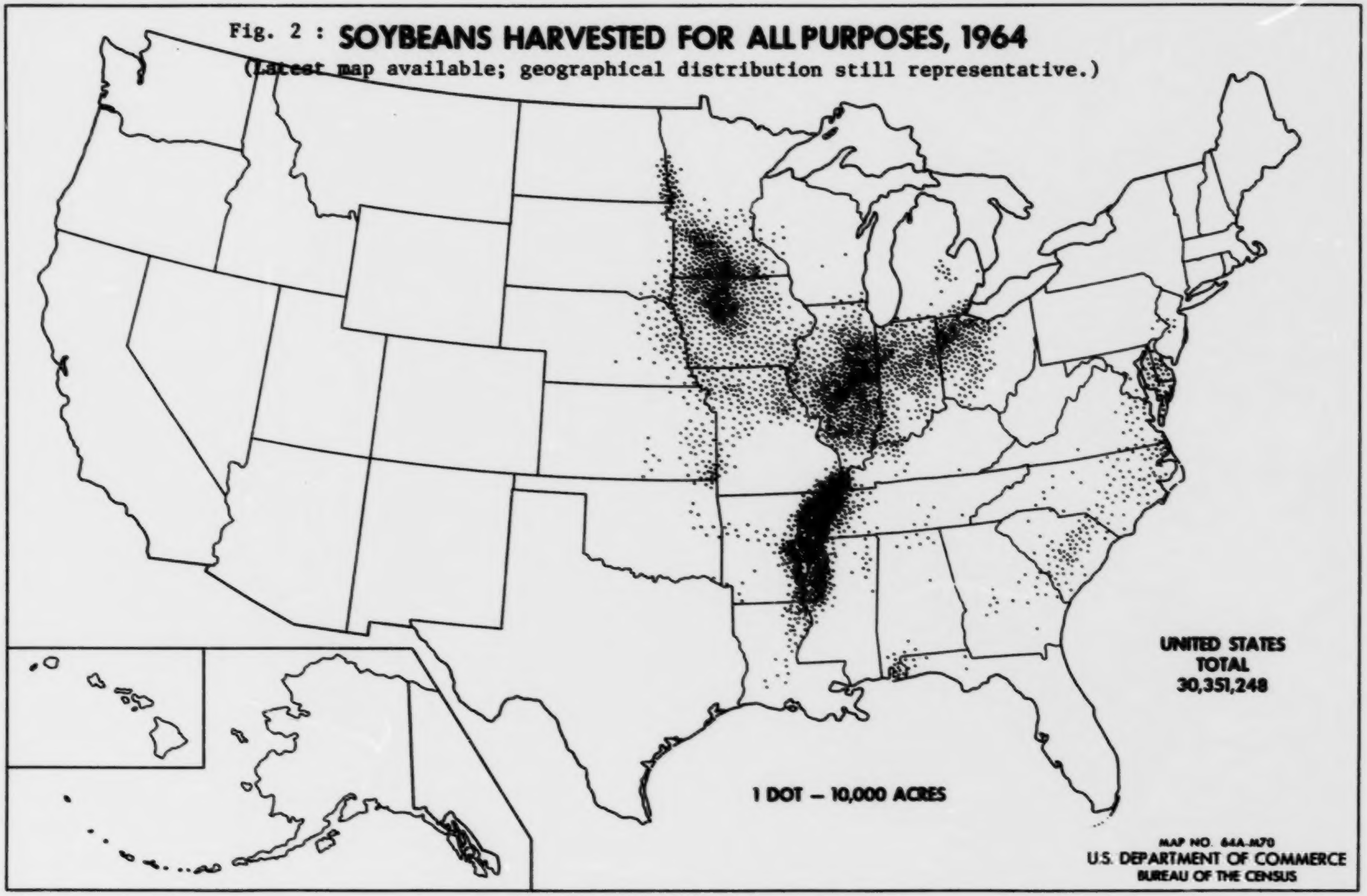

Table 3 : Land Use and Major Field Crops in the U.S. and in Iowa and Illinois, 1972.

(In Thousands of Acres)

State	Corn	Soybeans	Hay	Other	All Field Crops	Total Land in Farms	Total Land Area	Land in Farms/ Total Land Area
Iowa	11,100	6,070	2,300	2,030	20,800	33,710	35,800	94.2%
Illinois	9,395	7,500	1,220	2,685	20,800	29,200	35,700	81.8%
2 States	20,495	13,570	3,520	4,715	41,600	62,910	71,500	88.0%
U. S.	66,800	47,000	60,900	165,300	340,000	1,063,346	2,266,000	46.9%
2 States/U.S.	31%	29%	5.78%	2.85%	12.2%	5.92%	3.16%	

Sources: U. S. Department of Agriculture, 1972a, 1973b, 1973c.
Illinois Cooperative Crop Reporting Service, 1972, 1973a.
Iowa Crop and Livestock Reporting Service, 1973.

Table 3 summarizes land use and major field crops in Iowa and Illinois for 1972, compared to U. S. totals. The two states combined raised 20.5 million acres of corn in 1972, that is 31% of the total U. S. corn acreage (66.8 million acres). The two states raised 13.6 million acres of soybeans in 1972, equivalent to 29% of the U. S. total (47 million acres).

Iowa and Illinois combined cover only 3.2% of the total U. S. land area, but account for 5.9% of total land in farms, and 12.2% of the total acreage of all field crops. 94.2% of Iowa's total land area, and 81.8% of Illinois' total land area is land in farms. Thus, Iowa and Illinois are among the most intensively farmed land areas in the United States.

The use of chemical pesticides on corn and soybeans has increased substantially in recent years. The projected further increases in the production of both crops will undoubtedly result in increased crop protection needs. In view of the leading position of Iowa and Illinois in the production of corn and soybeans, it was decided to center this study in these two states.

B. General Characteristics of Farms and Farmers Interviewed.

The great majority of farms in Iowa and Illinois are relatively small in size. The number of farms and the average farm size in both states are as follows:

	Iowa	Illinois
Number of farms	132,610	123,000
Average size farm	254 acres	237 acres

(Sources: Illinois Cooperative Crop Reporting Service, 1972.
Iowa Crop and Livestock Reporting Service, 1973.)

As described in greater detail in the section on "Resources and Methods", a comprehensive field survey of about 300 farmers in both states was one of the key methods employed to accomplish the objectives of this study. The survey was focused on farms of 320 acres or larger. Studies by Beal and Bohlen (1957) indicate that larger farmers are usually the innovators and opinion leaders who initiate the adoption of new ideas in agriculture. Furthermore, a given number of larger farmers cover a larger share of the total acreage than if all farm sizes were equally represented. According to estimates by the Statistical Laboratory, Iowa State University, about 25% of all farms in Iowa are larger than 320 acres, and about 50% of the state's cropland area is in farms of this size. The farm size distribution in Illinois is very similar. The size of 320 acres is a logical break point because most farm sizes in the midwest are fractions or multiples of one "section", that is 1 square mile, or 640 acres.

Table 4 summarizes a number of general characteristics of the farms and farmers interviewed. The acreage operated by the respondents averaged 520 acres in Iowa, 597 acres in Illinois. The median farm size in the samples was 430 acres in Iowa, 505 acres in Illinois; the range was 320 - 1,200 acres in Iowa, 320 - 1,560 acres in Illinois.

Practically all farmers reported using "conventional tillage" practices, defined as "primary and secondary tillage operations normally performed in preparing a seedbed for a given crop; one of these operations usually being plowing". About two-thirds of the Iowa respondents, and about one-third of those in Illinois reported that they also used "minimum tillage", defined as "the minimum soil manipulation necessary for crop production", such as strip tillage or mulch tillage. (For more detailed definitions, refer to Appendix B .) 52% of the Illinois respondents also employed "no till" methods in 1973, defined as "a system whereby a crop is planted directly into a seedbed untilled since harvest of the previous crop".

Table 4 : Total Acreage Farmed, Tillage Practices, and Corn and Soybean Acreage Grown by Farmers Interviewed in Iowa and Illinois, 1973.

State	Iowa	Illinois
Number of farmers interviewed	58	239
Average number of acres farmed	520	597
Median number of acres farmed	430	505
Range of number of acres farmed	320-1,200	320-1,560
Percent of farmers using -		
- conventional tillage	100%	98%
- minimum tillage	66%	30%
- no till	0%	52%
Percent of farmers growing corn	100%	100%
Average number of acres of corn per corn grower	210	254
Corn rotation: Corn following -		
- corn	29%	37%
- soybeans	57%	50%
- sod or pasture	12%	10%
- another crop	2%	3%
Percent of farmers growing soybeans	97%	95%
Average number of acres of soybeans per soybean grower	176	224
Soybean rotation: Soybeans following -		
- soybeans	8%	16%
- corn	83%	74%
- another crop	9%	10%

Source: This study.

The rate of use of minimum tillage and no-till methods was unusually high in 1973 because an abnormally late and wet spring prevented more extensive tillage operations that would normally have been employed by many growers. Minimum tillage or no-till save time and tractor fuel and reduce soil erosion, but often require increased use of pesticides, especially herbicides.

All farmers interviewed in both states raised corn, and more than 95% of the interviewees also raised soybeans. The rotation patterns of corn and soybeans were quite similar in both states. In 1973, about one-half of all corn followed soybeans, about one-third followed corn, about 10% followed sod or pasture, and the balance another crop. About three-quarters of the soybeans grown in 1973 followed corn in the rotation, the balance being divided between soybeans on soybeans, and soybeans following another crop.

C. Corn and Soybean Production Costs and Prices.

Farmers' costs of producing corn at 110 bu./acre and soybeans at 35 bu./acre in Iowa in 1972 are summarized in Tables 5 and 6. The production costs for these crops in Illinois would be very similar. Stoneberg and Winterboer (1973) estimate the total production costs for corn at $130.31/acre ($1.18/bu.), for soybeans at $100.12/acre ($2.86/bu.).

A comparison of these production costs to the average prices received by farmers for corn and soybeans in 1972 (Tables 1 and 2) indicates that corn yielded an average profit of $0.42/bu., equal to $46.20 for 110 bu./acre. Soybeans yielded an average profit of $1.89/bu., equal to $66.15/acre for 35 bu./acre.

The production costs given by Stoneberg and Winterboer (1973) include $8.25/acre for herbicides and insecticides on corn, and $6.00/acre for herbicides on soybeans.

Table 5 : Cost of Producing Corn at 110 bu./acre on 320 - 440 Acre Farms in North Central Iowa, 1972

		Times	Cost Per Acre			Hours Per
		Over	Fixed	Variable	Total	Acre
I.	**Growing**					
	Chopping	1	$ .89	$ .44	$ 1.33	.17
	Disking	2	1.04	.80	1.84	.32
	Plowing	1	1.68	1.43	3.11	.40
	Harrowing	1	.32	.20	.52	.08
	Planting	1	1.15	.49	1.64	.21
	Hoeing	1½	.69	.39	1.08	.15
	Cultivating	1	.86	.48	1.34	.20
	P & K bulk spread	1	---	.60	.60	---
	Applying nitrogen	1	.46	1.07	1.53	.20
	Wagons, etc.		1.15	.60	1.75	---
	Total growing		$ 8.24	$ 6.50	$14.74	1.73 hrs
II.	**Harvesting and storage**					
	Combining		$ 6.58	$ 2.42	$ 9.00	.56
	Hauling 1½¢/bu.		.90	.75	1.65	.50
	Drying 6.5¢/bu.		2.50	4.65	7.15	.20
	Storage 3¢/bu.		3.30	----	3.30	---
	Total harvesting		$13.28	$ 7.82	$21.10	1.26 hrs.
III.	**Seed, chemicals, etc.**					
	Seed		---	$ 7.50	$ 7.50	
	Fertilizer 140-60-60[1] + lime		---	$17.55	$17.55	
	Herbicides		---	6.00	6.00	
	Insecticides		---	2.25	2.25	
	Total seed, chemicals, etc.		---	$33.30	$33.30	
IV.	**Farm Operating Overhead**		---	$ 4.50	$ 4.50	
V.	**Labor** @ $3.00 per hour					
	Direct - growing	1.73				
	harvesting	1.26				
	Indirect (+30%)	.90				
	Total labor	3.89 hr.	$11.67	---	$11.67	
VI.	Land @ $600 per acre					
	1½% for taxes		$ 9.00	---	$ 9.00	
	6% for interest		36.00	---	36.00	
	Total land		$45.00		$45.00	
VII.	**Total cost** - per acre		$78.19	$52.12	$130.31	
	- per bushel		.71	.47	1.18	

[1] N @ 5¢, P @ 9¢, K @ 5.25¢ per pound

Source: Stoneberg and Winterboer, 1973

Table 6 : Cost of Producing Soybeans at 35 bu./acre on 320 - 440 Acre Farms in North Central Iowa, 1972

	Times Over	Cost Per Acre			Hours per Acre
		Fixed	Variable	Total	
I. Growing					
Chopping	1	$ .89	$ .44	$ 1.33	.15
Disking	2	1.04	.80	1.84	.32
Plowing	1	1.68	1.43	3.11	.40
Harrowing	1	.32	.20	.52	.10
Planting	1	1.04	.49	1.53	.21
Hoeing	2	.86	.52	1.38	.20
Cultivating	1	.86	.48	1.34	.20
P & K bulk spread	1	---	.60	.60	---
Wagons, etc.		1.15	.60	1.75	---
Total growing		$ 7.84	$ 5.56	$13.40	1.58 hrs.
II. Harvesting and storage					
Combining		$ 3.95	$ 1.30	$ 5.25	.44
Hauling 3¢/bu.		.55	.50	1.05	.20
Storage 3¢/bu.		1.05	---		---
Total harvesting		$ 5.55	$ 1.80	$ 7.35	.64
III. Seed, chemicals, etc.					
Seed		---	$ 9.00	$ 9.00	
Fertilizer 0-40-40 + lime		---	7.70	7.70	
Herbicides		---	6.00	6.00	
Total seed, chemicals, etc.		---	$22.70	$22.70	
IV. Farm operating overhead		---	$ 3.00	$ 3.00	
V. Labor @ $3.00 per hour					
Direct-growing	1.58				
harvesting	.64				
Indirect (+30%)	.67				
Total labor	2.89	$ 8.67	---	$ 8.67	
VI. Land @ $600 per acre					
1½% for taxes		$ 9.00	---	$ 9.00	
6% for interest		36.00	---	36.00	
Total land		$45.00	---	$45.00	
VII. Total cost - per acre		$67.06	$33.06	$100.12	
per bushel		1.92	.94	2.86	

Source: Stoneberg and Winterboer, 1973

The Illinois Farm Management Manual (Hinton, 1972) includes a tabulation (Table 7) of the direct costs (exclusive of the cost of land, taxes, interest, indirect labor, and farm operating overhead that are included by Stoneberg and Winterboer, Tables 5 and 6) for growing crops on 260 - 359 acre farms at different yield levels. The dollar costs allocated to "sprays and other materials" for corn and soybeans appear to be unrealistically low, but the interesting point is that they increase by 150% (from $2.00 to $5.00/acre) as the corn yield increases by 50% (from 80 to 120 bu/acre). In the case of soybeans, Hinton's costs for "sprays and other materials" increase only by 14% (from $3.50 to $4.00/acre) as the yield increases by 52% (from 33 to 50 bu. per acre). These figures indicate farm managers' expectations that increased per-acre yields of corn and soybeans require increased pesticide inputs, a finding that is especially significant in the light of the projected substantial increases in the yields and acreages of corn and soybeans in the next 10 years (Tables 1 & 2).

During 1973 when this study was in progress, farm prices for corn and soybeans gyrated considerably (Table 8). Prices per bushel of corn ranged from a low of $1.35 in February to a high of $2.68 in August, settling back to $2.15 - $2.18 in September, October and November. In February of 1974, market prices for corn were quoted at around $3.00/bu.

Farm prices per bushel of soybeans varied by even wider margins, from a low of $4.10 in January of 1973 to a high of $10.00 in June, settling back to $5.63 in October. In February of 1974, market prices for soybeans were quoted at around $6.20 - $6.30/bu. (February 1974 market prices for corn and soybeans quoted from the Wall Street Journal of February 8, 1974.)

Table 8 also includes for both crops a computation of the effects of the monthly commodity prices on the value of an acre of

Table 7 : Direct Crop Costs and Hours of Man Labor and Tractor Use Per Acre for Growing and Harvesting Crops on 260-359 Acre Farm[a/]

Item	Corn 80 bu.	Corn 100 bu.	Corn 120 bu.	Soybeans 33 bu.	Soybeans 50 bu.	Wheat 40 bu.	Wheat 55 bu.	Oats	Winter barley	Grain sorghum
Preharvest										
Power and machinery										
Depreciation	$ 6.00	$ 6.00	$ 6.00	$ 6.00	$ 6.00	$ 3.00	$ 3.00	$ 3.00	$ 3.00	$ 6.00
Repairs and fuel	3.50	3.50	3.50	3.50	3.50	1.40	1.40	1.40	1.40	3.50
Custom machine hire	....	....	....	....	....	....	....	....	....	....
Seed or plants	4.00	6.00	8.00	3.00	4.00	2.80	3.50	2.00	2.20	1.00
Sprays and other materials	2.00	3.50	5.00	3.50	4.00	.70	.80	.50	.50	3.50
Seasonal hired labor	....	....	....	....	....	....	....	....	....	....
Harvest and condition										
Seasonal hired labor	....	....	....	....	....	....	....	....	....	....
Power and machinery										
Depreciation	10.00	10.00	10.00	4.00	4.00	4.00	4.00	4.00	4.00	9.00
Repairs and fuel	3.10	3.60	4.10	1.30	1.50	1.30	1.50	1.30	1.30	5.00
Custom machine hire	1.60	2.00	2.40	.70	1.00	.80	1.10	....	....	....
Other materials	.80	1.00	1.20	....	....	....	....	....	....	1.00
Total direct costs.	$31.00	$35.60	$40.20	$22.00	$24.00	$14.00	$15.30	$12.20	$12.40	$ 29.00
Total, excluding depreciation.	$15.00	$19.60	$24.20	$12.00	$14.00	$ 7.00	$ 8.30	$ 5.20	$ 5.40	$ 14.00
Cost of fertilizer nutrient removal per unit of yield	.14	.14	.15	.18	.17	.21	.20	.11	.14	.15
Farm man labor (hours)	4.4	4.5	4.6	4.5	4.6	2.0	2.1	2.0	2.0	5.0
Tractor and self-propelled power (hours)	3.7	3.8	3.9	3.0	3.1	1.5	1.6	1.5	1.5	4.0
Yield per acre (bushels)	80.0	100.0	120.0	33.0	50.0	40.0	55.0	67.0	50.0	80.0

[a/] Adapted from 1964-1970 cost data on Illinois farms.

Source: Hinton, R. A. 1972

Table 8 : Farm Prices and Value/Acre of Corn and Soybeans by Months, 1973

Month	Corn		Soybeans	
	Farm Price, $/bu.	Value, $/acre 1/	Farm Price, $/bu.	Value, $/acre 2/
Jan.	1.39	153.60	4.10	145.55
Feb.	1.35	149.18	5.49	194.90
Mar.	1.37	151.39	6.05	214.78
Apr.	1.42	156.91	6.14	217.97
May	1.61	177.91	8.27	293.59
June	1.99	219.90	10.00	355.00
July	2.03	224.32	6.69	237.50
Aug.	2.68	296.14	8.99	319.15
Sept.	2.15	237.58	5.81	206.26
Oct.	2.17	239.79	5.63	199.87
Nov.	2.18	240.89	n.a.	

1/ Based on yield of 110.5 bu./acre. Average 1972 yields were 110 bu./acre in Illinois, 111 bu./acre in Iowa.

2/ Based on yield of 35.5 bu./acre. Average 1972 yields were 35 bu./acre in Illinois, 36 bu./acre in Iowa.

Sources: U. S. Dept. of Agriculture, 1973b, c.
Illinois Cooperative Crop Reporting Service, 1973a.
Iowa Crop and Livestock Reporting Service, 1973.

corn at 110.5 bu./acre, and of an acre of soybeans at 35.5 bu. per acre. The value of the crop as perceived by the grower at the time when he has to decide whether or not to use a pesticide will, of course, influence that decision. This became very apparent, for instance, in the summer of 1973 when foliar soybean insects in the study area started to feed on soybeans that were, at that time, worth about $9.00/bu., or $320/acre. These events will be discussed in greater detail below in Section VI, Soybean Insects.

IV. USES AND COSTS OF PESTICIDES IN THE MIDWEST

This section presents an overview of the use of pesticides in the Midwest, including total quantities used, and rates of application and grower costs of major corn and soybean insecticides and herbicides, followed by an overview of the crop protection practices of the Iowa and Illinois farmers interviewed in this study. Many of these information items are discussed in greater detail in other sections of this report, but it was felt desirable to present them once in a manner that permits comparisons between herbicides, insecticides and fungicides, and between weed and insect control practices. This section of the report serves that purpose.

According to estimates by the U. S. Department of Agriculture 1968b, 1970b, 1974), the use of herbicides and insecticides in the "corn belt" region (Illinois, Indiana, Iowa, Missouri, and Ohio) increased rapidly during the 8-year period, 1966 - 1971 (Table 9). Corn herbicides accounted for more than one-half of the total quantity of all pesticides used on all crops in this region in 1971, followed by soybean herbicides and corn insecticides. All other pesticide uses combined, including herbicides on crops other than corn and soybeans, insecticides on crops other than corn, and fungicides on all crops, make up only about 7% of the total quantity of pesticides used.

Estimates from other sources on the quantities of pesticides used in the Midwest indicate that those by the U. S. Department of Agriculture summarized in Table 9 may be too low (refer to pp. 49 ff. below). However, the relative orders of magnitude evident in Table 9 are realistic.

This study was initially focused on the three major pesticide uses in the area, i.e., the control of weeds in corn and

Table 9: Quantities of Pesticides Used on Farm Crops in the Corn Belt[1] in 1964, 1966 and 1971 (In Thousands of Lbs. of Active Ingredients).

Pesticide/Crop	1964	1966	1971
Herbicides on			
Corn	12,590	27,473	54,069
Soybeans	3,024	6,567	18,875
All Other Crops	1,381	1,440	3,407
All Crops	16,995	35,480	76,351
Insecticides on			
Corn	10,812	17,525	15,314
Soybeans	516	244	117
All Other Crops[2]	3,030	3,688	2,993
All Crops	14,358	21,457	18,424
Fungicides on			
Corn	0.1	negl.	negl.
Soybeans	0.2	negl.	negl.
All Other Crops[2]	7.9	5.4	5.3
All Crops	8.2	5.4	5.3

1/ Corn Belt = Illinois, Indiana, Iowa, Missouri, and Ohio.

2/ Apples, vegetables, other field crops (mainly outside of Illinois and Iowa)

Sources: U. S. Department of Agriculture, 1968b, 1970b, 1974.

soybeans, and the control of insects on corn. An unexpected infestation of foliar insects on soybeans developed while the study was already in progress. It was too late at that time for inclusion of this problem in the farmer survey, but other aspects of the soybean insect situation were studied and are reported in the section on "Soybean Insects".

The combined corn acreage of Iowa and Illinois accounts for about two-thirds of all corn acres in the 5-state "corn belt". The combined soybean acreage of the two states makes up close to 60% of all soybeans grown in the corn belt. Accordingly, it is estimated that about two-thirds of all pesticides used on corn and soybeans in the corn belt are used in Iowa and Illinois.

Table 10 lists the major corn and soybean herbicides and insecticides used in Iowa and Illinois, their rates of application as recommended by the Extension Service and by the pesticide trade, and approximate grower costs based on the rates recommended by the trade. There are no serious discrepancies between the rates recommended by the different sources. The Iowa Extension Service does not recommend rates of application for herbicides. Thus, those listed in the Extension Service column are from Illinois only. Conversely, Illinois Extension does not recommend the use of aldrin (or other chlorinated hydrocarbon soil insecticides), and the rates in the Extension column in this case are those recommended in Iowa.

In some instances, pesticides can be applied "piggyback" in conjunction with tillage or cultivating operations. In this case, application costs would be very small and are often not counted. Otherwise, when the pesticide application requires a special pass over the field (mostly by ground, sometimes by air equipment), application costs are usually $1.00 to $1.50/acre, not including the cost of the pesticide.

Table 11 summarizes the crop protection practices of the

Table 10: Recommended Rates of Application and Approximate Grower Costs of Selected Corn and Soybean Insecticides and Herbicides in Iowa and Illinois, 1973

Pesticide	Rate Recommended By Extension Service Lb.AI/Acre	 Pesticide Trade Lb.AI/Acre	Approximate Grower Cost $/Acre
Corn Herbicides [1/]			
Atrazine (80WP)	0.8 - 4.0	2.0 - 3.2	6.10 - 9.80
Propachlor (65WP)	4.0 - 4.9	4.0 - 6.0	8.75 - 13.15
Butylate (6EC)	4.0	3.0 - 4.0	5.80 - 7.75
Soybean Herbicides [1/]			
Trifluralin (4EC)	0.5 - 1.0	0.75 - 1.0	4.70 - 6.25
Chloramben (2EC)	3.0	2.0 - 3.0	9.75 - 14.60
Alachlor (4EC)	2.5 - 3.0	2.0 - 3.0	6.70 - 10.00
Corn Insecticides			
Aldrin	2.0 - 4.0 [2/]	1.0 - 3.0	1.60 - 4.80
Phorate (15G)	1.0	0.75 - 1.0	1.85 - 2.40
Carbofuran (10G)	0.75	0.75 - 1.0	3.30 - 4.40
Soybean Insecticides			
Carbaryl (80WP)	1.0 - 1.6	1.6	2.00
Malathion (5EC)	1.0	1.0	2.00
Toxaphene (6EC)	2.0	1.5	0.80

1/ Iowa does not recommend rates of application for herbicides. Rates given are from Illinois recommendations.

2/ Not recommended in Illinois.

Sources: Illinois Cooperative Extension Service
1973 Field Crops Weed Control Guide, 11-72
1973 Suggested Insecticide Guides, Circ. 899, Dec. 1972

Iowa Cooperative Extension Service
1973 Herbicides for Weed Control in Corn and Soybeans, WC-86 Rev., Nov. 1972
1973 Insect Pest Control Recommendations, IC-328 Rev., Feb. 1973

Pesticide Trade Literature and Information

Table 11: Iowa and Illinois Farmers' Crop Protection Practices, 1973.

% Respondents		
Iowa	Illinois	
		Corn Herbicides.
100	99	--used corn herbicides in 1973.
70	42	--changed products at least once since 1970.
97	94	--considered herbicide efficacy satisfactory or better in 1972 and 1973.
88	82	--believe all of their corn acres need herbicides each year.
62	56	--would not change herbicide use if cost would double.
97	97	--would continue to grow corn if no herbicides were available.
		Corn Insecticides.
53[2/]	70[2/]	--used corn insecticides in 1973.
52[1/]	43[1/]	--changed products at least once since 1970.
100[1/]	94[1/]	--considered insecticide efficacy satisfactory or better in 1972 and 1973.
55[1/] 29[2/]	55[1/] 39[2/]	--believe all of their corn acres need insecticides each year.
77[1/]	61[1/]	--would not change insecticide use if cost would double.
97[1/]	94[1/]	--would continue to grow corn if no insecticides were available.
		Soybean Herbicides.
98	98	--used soybean herbicides in 1973.
58	45	--changed products at least once since 1970.
92	85	--considered herbicide efficacy satisfactory or better in 1972 and 1973.
96	86	--believe all of their soybean acres need herbicides each year.
72	67	--would not change herbicide use if cost would double.
76	79	--would continue to grow soybeans if no herbicides were available.

1/ % of corn insecticide users

2/ % of corn growers

For general characteristics of farms and farmers interviewed, refer to Table 4, page 23.

Iowa and Illinois farmers interviewed in this study in 1973. 98 - 100% of the respondents in both states used herbicides on corn and soybeans, and a high percentage of them consider this a very essential practice. By contrast, only 53 (Iowa) to 70% (Illinois) of the farmers interviewed used corn insecticides in 1973; and only 55% of this group, that is only about one-third of all corn growers, believed that all of their corn acres need insecticide treatments each year. Other aspects of the results of the farmer survey will be reported and evaluated in greater detail in the following sections of this report.

V. CORN INSECTS

A. Major Insect Pests

Corn in Iowa and Illinois may be affected by soil as well as by foliar insects. The soil insects are considerably more detrimental. They consist of several species of corn rootworms, and a number of other insects often referred to as the "soil insect complex".

There are three species of corn rootworms in the area, i.e., *Diabrotica longicornis*, the northern corn rootworm, *D. virgifera*, the western corn rootworm; and *D. undecimpuncata howardi*, the southern corn rootworm. The northern and western species predominate in Iowa and Illinois. The two species occur together and have very similar life cycles and habits.

The "soil insect complex" includes seedcorn maggots, *Hylemya* spp.; the seedcorn beetle, *Agonoderus lecontei*; the slender seedcorn beetle, *Clivina impressifrons*; wireworms (order *Coleoptera*, family *Elateridae*); cutworms (order *Lepidoptera*, family *Noctuidae*); white grubs, *Phyllophaga* or *Lachnosterna* spp.; webworms, *Crambus* spp.; billbugs, *Calendra* spp.; ants (order *Hymenoptera*, family *Formicidae*); and the corn root aphid, *Anuraphis maidiradicis*.

These soil insects are most serious on first-year corn following legumes, legume-grass or grass sods. They are seldom a problem on corn following corn or soybeans in the rotation.

Corn rootworms are usually a problem only on corn following corn, sorghum or sunflowers. Corn following soybeans or small grains rarely suffers rootworm damage.

Foliar insects that may attack corn in the midwest include corn borers, (order *Lepidoptera*, family *Pyralididae*); corn earworm, *Heliothis zea*; and corn rootworm beetles, the adult forms of the corn rootworms (*Diabrotica* spp.) discussed earlier. Foliar corn insects are generally much less of a threat to corn yields than corn soil insects.

B. Losses Due to Insects and Benefits from their Control.

Entomologists at the University of Illinois have studied insect infestations and potential yield losses in field crops since 1955 (Petty, 1974). An estimate of the acres of Illinois field crops treated with insecticides, and of the profits obtained from such treatments is compiled annually from reports by county extension advisors. Table 12 presents this estimate for 1973 as given by Randell et al. (1974). According to these authors, Illinois field crop growers realized an estimated net return of over $24 million from the use of insecticides in 1973 ($23.8 million in 1972).

Table 12 indicates that about 84% of the total estimated profit realized in 1973 ($20,083,186 of a total of $24,018,473) resulted from the control of corn rootworms by insecticides. In response to our request, one of Randell's co-authors, D. E. Kuhlman (1973), provided further information on how these estimates were derived. Table 13 summarizes the estimates by Randell, Kuhlman and others on the use and profitability of soil insecticides for the control of corn rootworms in Illinois during the 10-year period 1964-1973. The methods by which these figures were obtained are outlined in Footnote 2. According to these investigators, approximately 6 million acres of corn in Illinois were treated with soil insecticides during the last 3 years, but only about 40% of these (2.5 million acres) were treated profitably with corn rootworm insecticides. This estimate is based on a survey of adult corn rootworm populations in Illinois in 1971. On these 2.5 million acres of corn where rootworm control was needed, the average yield loss prevented was estimated at 10% = 10 bu./acre. On the remaining 3.5 million acres (60%), the use of soil insecticides yielded an estimated average profit of only $1.00/acre over and above the cost of treatment.

Table 12 *Acres of Field Crops Treated With Insecticides and Profit From Treatments, Illinois, 1973, Estimated From Reports by County Extension Advisers*

Crop and insect	Acres treated	Estimated profit[a]
Corn		
Armyworms	19,593	$ 29,390
Corn rootworm adults	24,642	98,568
Corn leaf aphids	137,292	961,044
Cutworms	93,781	562,686
European corn borers	108,284	162,426
Grasshoppers	12,829	12,829
Soil insects	5,738,053	20,083,186[b]
Fall armyworms	124,063	310,158
TOTAL	6,258,537	$22,220,287
Soybeans		
Green cloverworms	735,917	$ 1,103,876
Grasshoppers	2,435	7,305
Cutworms	8,490	50,940
TOTAL	746,842	$ 1,162,121
Wheat		
Armyworms	12,870	$ 51,480
Sorghum		
Webworm, fall armyworm, etc.	28,496	$ 42,744
Clover and alfalfa		
Alfalfa webworms	478	$ 2,868
Alfalfa weevils	105,461	421,844
Pea aphids	3,800	7,600
Grasshoppers	33,261	99,783
Meadow spittlebugs	539	1,078
Potato leafhoppers	4,334	8,668
TOTAL	147,873	$ 541,841
1972 TOTAL	6,768,851	$23,765,461
1973 TOTAL	7,194,618	$24,018,473

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[a] Over and above treatment costs.

[b] Based on yield increase from use of rootworm insecticides.

From: Randell et al., 1974

Table 13: Estimated Use and Profitability of Soil Insecticides for Corn Rootworm Control in Illinois, 1964 - 1973.

Year	Corn Acres Treated with Soil Insecticides	Average Profit 1/ $/Acre	Total Profit, $
1964	4,091,125	4.00	16,364,500
1965	4,733,784	5.00	23,668,920
1966	5,443,197	5.00	27,215,985
1967	6,204,293	5.00	31,021,465
1968	6,261,869	5.00	31,309,345
1969	6,508,067	5.00	32,540,335
1970	6,610,287	3.75	24,788,576
1971	6,142,039	3.50 2/	21,497,137
1972	6,085,328	3.50	21,298,648
1973	5,738,053	3.50	20,083,186
10 Years			249,788,097

1/ Average return above cost of treatment for all corn soil insecticide users.

2/ This estimate, $3.50/acre, based on following assumptions:

Cost of insecticide treatment = $3.00/acre. Farm price of corn = $1.00/bu. Average saving in yield loss for 40% of treated acres = 10% = $10.00/acre, less cost of treatment = $7.00/acre net. 60% of treated acres obtained only $1.00/acre net return above cost of treatment. Estimated average return for all corn soil insecticide users = $3.50 per acre.

Higher average profit estimates for earlier years are based on greater severity of the corn rootworm problem, resulting in greater yield loss savings.

Sources: Randell et al, 1974; Kuhlman, 1973.

Illinois corn growers realized estimated cumulative profits of about $250 million from the use of corn rootworm insecticides during the last 10 years. Estimated annual profits reached a high of $32.5 million in 1969, declining steadily thereafter, to about $20 million in 1973. This downward trend is attributed to a lessening of the corn rootworm problem since 1970. Prior to 1970, corn rootworm populations were considerably higher and thus more damaging, and the return from using insecticides to control them was greater. Whether this downward trend will continue in the future will depend, among other things, on future corn rotation patterns. Entomologists expect that corn rootworm problems will continue to exist in continuous corn; if soybean acreage increases, continuous corn acreage will decrease, and so will rootworm problems.

Foliar (above ground) insects of corn are not nearly as important from the standpoint of economic damage potential as the soil insects. Randell et al. (1974) estimated that Illinois corn growers profited about $1.6 million from the use of insecticides against foliar corn insects (armyworms, corn rootworm adults, corn leaf aphids, European corn borers, grasshoppers, fall armyworms), compared to estimated profits of $20.6 million from using insecticides against soil insects, including cutworms (Table 12). Control of corn leaf aphids on 137,000 acres accounted for $961,044, almost two-thirds of the total estimated profits from using foliar corn insecticides. In 1972, corn leaf aphids were controlled profitably on 55,669 acres in Illinois, yielding an estimated profit to growers of $389,683 (Kuhlman et al. 1973), while armyworms, corn rootworm adults, European corn borers, and grasshoppers were of minor economic importance.

The figures on the estimated economic benefits from the use of insecticides on field crops in Illinois discussed in this section are presented and quoted exactly as given in the sources cited. One might question whether estimates can possibly be accurate to single acres or dollars. One might also question the methodology and assumptions outlined by Kuhlman (Table 13, Footnote 2); and perhaps other details whose pursuit would be beyond the scope of the present study. The information in Tables 12 and 13 was rendered "as is" despite these reservations because it is widely accepted and used by entomologists, extension personnel, pesticide sellers, and by farmers themselves, i.e., by the people whose collective opinions and actions govern the use of pesticides and/or other crop protection measures in the study area.

Furthermore, it is pointed out that the Illinois entomologists' estimates assume a farm price of corn of $1.00/bu. The actual average farm price per bu. of corn was $1.08 in 1971, $1.60 in 1972 (Table 1). In 1973, it reached as high as $2.68 in August (Table 8), while the average for the year was estimated at $2.30. The costs of insecticides may have increased somewhat, but not nearly at the same rate. Thus, the cost of insecticide treatment in 1973 was equivalent to the value of less than 1.5 bu. of corn, compared to 3.0 bu. assumed by Kuhlman (1973), making the insecticide use relatively more attractive.

Comparable estimates on profits from the use of insecticides on corn are not available for Iowa. However, a comparison between Iowa and Illinois insect control recommendations, as well as discussions with entomologists in both states indicate that the relative economic importance of corn insects in Iowa is very similar to that in Illinois.

C. Use Patterns of Insecticides on Corn.

In the early days of the use of soil insecticides on corn, chlorinated hydrocarbon insecticides controlled both corn rootworms and the complex of other soil insects. Today, western corn rootworms are completely, and northern corn rootworms almost completely resistant to the cyclodiene insecticides in Iowa and Illinois. Thus, it has become a widely adopted practice to use chlorinated hydrocarbon insecticides against the soil insect complex, and organic phosphate and/or carbamate insecticides against resistant corn rootworms.

One vexing problem with the soil insects other than corn rootworms is that they occur rather erratically and only in spots, even in situations where they would be expected to be a problem because of the rotation pattern. For instance, entomologists wishing to conduct insecticide performance trials against these insects find it very difficult to obtain meaningful field test results because infestations are so unpredictable. Oftentimes, no insects are present in nine out of ten trials. These field experiences indicate that in all probability, only a small percentage of the corn acreage in Iowa and Illinois that is currently treated with chlorinated hydrocarbon insecticides against these soil insects really needs the treatment. The problem is that at the present state of the art, it is impossible to predict which field or which part of a given field may or may not be damaged by soil insects. Since preventive insecticide treatments are relatively inexpensive (Compare Tables 8 and 10), many growers apply them.

Because of increasing insect resistance to chlorinated hydrocarbon insecticides and mounting residue problems (see section on "Side Effects" below), Illinois began advising against the use of these insecticides on dairy farms in 1965. In 1970, Illinois discontinued the state recommendations for the use of chlorinated hydrocarbon insecticides on corn altogether. The "1971 Suggested Insecticide Guides/Insect Control for Field Crops" issued by the University of Illinois Cooperative Extension Service in December of 1970 states in part as follows:

> "The previous history of use (of aldrin and heptachlor) in Illinois indicates that in about 5 million acres to be planted to corn, residues of dieldrin/aldrin or heptachlor epoxide-heptachlor may exert such a depressing effect on the general pest population that continued applications would not be needed.

> Selecting fields that warrant the use of aldrin or heptachlor is important. A few hundred thousand acres of corn could be profitably treated broadcast with aldrin or heptachlor to control black cutworms, but these fields cannot be selected until the damage has already occurred. To prevent this damage, it would be necessary to apply one of these insecticides to 3 or 4 million acres in Illinois. It is cheaper to apply control measures when cutworms appear."

The last sentence of this quotation is probably undebatable considering the state as a whole. However, many individual growers are left with the uncertainty whether or not their particular fields would be among those where cutworm treatments would be profitable, and many of them opt for preventive treatment. From an overall standpoint, this results in a considerable amount of unnecessary and thus wasteful insecticide use. At the same time, most growers consider their individual use of the insecticide a protection against possible yield losses and thus a necessary and prudent investment.

This dilemma is further illustrated by the fact that in the current legal proceedings in connection with the proposed cancellation of many registrations of aldrin, widely divergent views have been presented in court in sworn testimony by expert witnesses on whether the use of aldrin as a soil insecticide on corn and other crops is wasteful or essential. No generally accepted definitions or criteria have been established on what constitutes a wasteful pesticide use, and very few, if any studies have been undertaken to delineate and quantify wasteful pesticide use practices.

Petty (1974) monitored the use of corn soil insecticides in Illinois during the period 1966-1972 by three different survey methods (Table 14). The total acreage treated with soil insecticides remained relatively constant during this period, but the number of acres treated with chlorinated hydrocarbons decreased remarkably, while the use of other insecticides, primarily organic phosphates and carbamates, increased from a very small acreage treated in 1966 to 3 to 4 million acres in 1972.

In view of the intense current debate on the need for continued availability of aldrin for control of corn insects, Petty also compared corn yields in southern, central and northern Illinois with the use of chlorinated hydrocarbon insecticides in these areas in 1966, 1968-1969, and 1971-1972 (Table 15). In all three areas, corn yields continued to increase while the use of chlorinated hydrocarbon insecticides (primarily aldrin) decreased from 66 to 39% in southern Illinois, from 64 to 14% in central Illinois, and from 57 to 8% in northern Illinois. Petty's comments on these figures are as follows:

> "Some people ask about average yields and the effect of decreasing use of chlorinated hydrocarbons. These comparisons are difficult to make with great reliability, but some data are available by sections. When we compare yields in bushels per acre and percent of acres treated with chlorinated hydrocarbons, we find an inverse relationship. As use has decreased, yields have increased since 1966 (Table 15). That this positive correlation can be drawn is open to question, but it is not questioable that a conclusion can be drawn that this decrease in use did not affect yields adversely."

The Iowa Cooperative Extension Service has continued to recommend aldrin, heptachlor and chlordane for use against corn soil insects, except on dairy farms, up to and including 1973. We understand that these recommendations will be continued in 1974. Stockdale (1971, 1973) estimated that in 1971, about 6.5 million acres of corn in Iowa were treated with soil insecticides, 2.75 million of these (42%) with chlorinated hydrocarbons (aldrin 90%; heptachlor 8%; chlordane 2%), the balance with organic phosphates and carbamates. In 1973, an estimated 5 million acres of corn in Iowa were treated with soil insecticides, 2.5 million of these (50%) with chlorinated hydrocarbons (aldrin 80%; heptachlor 16%; chlordane 4%).

Table 14: *Thousands of Acres Treated With Soil Insecticides in Illinois, a Comparison of Three Methods of Measuring*[a]

Year	Total acres treated			Acres treated with chlorinated hydrocarbons			Acres treated with other insecticides		
	EA	RS	ICR	EA	RS	ICR	EA	RS	ICR
1966	5,443.2	6,648.1	...	5,116.6	6,473.3	...	326.6	174.8	...
1967	6,204.3	...	...	5,601.6	...	...	602.7	...	...
1968	6,261.8	5,775.7	...	5,170.7	4,347.0	...	1,091.1	1,428.7	...
1969	6,508.0	6,018.8	7,071	4,517.9	4,111.2	4,631	1,990.1	1,907.6	2,440
1970	6,610.2	6,314.8	5,770	3,844.7	3,576	3,214	2,765.5	2,738.8	2,556
1971	6,142.0	5,894.1	5,488[d]	1,881.6[b]	2,154.9[b]	2,777	3,418.9	3,739.2	2,711[d]
1972	5,785.3	5,522.2	5,511[d]	2,051.7[c]	1,820.7[c]	2,376[d]	3,852.2	3,701.5	3,135[d]

[a] Methods used included questionnaires submitted to county extension advisers for their estimates (EA); random surveys of 22 counties and 10 fields per county for corn rootworm adult populations with a follow-up and field histories, obtained by interviews (RS); and interviews by Illinois Crop Reporting Service employees (ICR).

[b] Published figure, 2,723,000 acres, was adjusted because of distributor and dealer sales reported to us.

[c] Published figure, 1,933,100 acres, was an average of RS and EA.

[d] These figures added to Petty's original table.

From: Petty, 1974

Table 15: Comparison of Corn Yields in Bushels per Acre and Percent of Total Acreage Treated With Chlorinated Hydrocarbons, 1966, 1968-1969, 1971-1972[a]

Area		1966	1968-1969	1971-1972
Southern Illinois	Bushels per acre	67.7	84.8	94.2
	Percent of acres treated	65.8	57.9	39.1
Central Illinois	Bushels per acre	85.1	97.7	116.3
	Percent of acres treated	63.9	35.3	13.7
Northern Illinois	Bushels per acre	73.2	97.5	103.7
	Percent of acres treated	56.8	34.3	7.8

[a] Data for 1967 were incomplete; southern corn blight interfered with yields in 1970.

From: Petty, 1974

We queried entomologists in both states about this situation. There was consensus that from the standpoint of insect infestations and damage potential, there is no greater or lesser need for chlorinated hydrocarbon soil insecticides in Iowa than in Illinois. In fact, if there are any differences in this regard, they would be in the direction of a somewhat greater need for these persistent insecticides in Illinois. The decline in the use of chlorinated hydrocarbon insecticides in Illinois was attributed primarily to the recommendations against their use by the Illinois Cooperative Extension Service, probably supported by more vigorous monitoring for aldrin/dieldrin residues, and the expectation of more vigorous law enforcement in cases of illegal residues.

Iowa extension entomologists feel that aldrin is still needed on about 1 million acres of corn in their state (that is about one-half of the acreage actually treated with aldrin in 1973), primarily for the control of the black cutworm, *Agrotis ypsilon*, an insect whose occurrence is difficult to predict in areas generally known to be susceptible to infestations. In untreated fields, black cutworm infestations are usually not detected until after considerable damage has already occurred, and emergency spray or bait treatments are too late, Iowa entomologists point out.

Illinois entomologists treat the black cutworm problem as follows in their "1973 Suggested Insecticide Guides/Insect Control for Field Crops":

> "Black cutworms have been controlled adequately with apple pomace-carbaryl pelleted baits, but early detection and application are essential. Late application kills the cutworms but much of the damage has already been done. Baits are less successful with extreme drouth or excessive rainfall. Carbaryl or trichlorfon liquid sprays or spray baits are also effective, but must be directed at the base of the plants."

According to the estimates by the U. S. Department of Agriculture (1968b,1970b, 1974) mentioned in Sec. IV above, the use of insecticides on corn in the "corn belt" (Illinois, Indiana, Iowa, Missouri, and Ohio) was 10.8 million lbs. in 1964; 17.5 million lbs. in 1966; and 15.3 million lbs. in 1971 (Table 9). A comparison of these figures to the quantities of insecticides used on corn in the entire U. S. (Table 16) indicates that 69% of all corn insecticides were used in the five corn belt states in 1964; 74% in 1966; and 60% in 1971.

The USDA's estimate of the quantity of insecticides used on corn in the corn belt states in 1971 (15.3 million lbs.) is surprisingly low, and difficult to reconcile with the data reported by Petty (1974) and Stockdale (1971). Combining Petty's and Stockdale's well supported estimates on the corn acreage treated with insecticides in Iowa and Illinois in 1971 with the corresponding rates of application, the quantities used would be as follows:

	Acres Treated (000)		Rate Lbs. AI /Acre1/	Total Quantity Lbs. AI (000)
	Iowa	Illinois		
Soil insecticides:				
Chlorinated hydrocarbons	2,750	2,200	1.3	6,435
Other insecticides	3,750	3,800	1.0	7,550
Subtotals	6,500	6,000		
Totals, both states	12,500			13,985
Foliar insecticides (against corn borers, cutworms and grasshoppers):	3,000		1.5	4,500
Totals	15,500			18,485

1/ Table 10; Wiersma et al. 1972; Carey et al. 1973

Table 16: Quantities of Insecticides Used on Corn in the U.S., and on Farm Crops in the Corn Belt[1] in 1964, 1966 and 1971, By Chemical Groups.

Chemical Group	Corn/United States			All Crops/Corn Belt[1]		
	1964	1966	1971	1964	1966	1971
	------- Thousands of lbs. of active ingredients -------					
Chlorinated Hydrocarbons	12,160	16,226	10,046	11,790	15,599	9,651
Organic Phosphates	3,390	6,733	7,515	1,709	3,568	4,313
Carbamates	107	669	7,905	547	2,290	3,815
Others[2]	11	1	65	312	--	645
All Insecticides	15,668	23,629	25,531	14,358	21,457	18,424

1/ Corn Belt = Illinois, Indiana, Iowa, Missouri, and Ohio.

2/ Primarily inorganic insecticides.

Sources: U. S. Department of Agriculture, 1968b, 1970b, 1974.

According to these estimates, the quantities of insecticides used on corn in Iowa and Illinois alone in 1971 exceed the USDA estimate for the entire corn belt (Table 9) by more than 3 million lbs. Iowa and Illinois raised 64% (21.8 million acres) of all corn acres in the corn belt (33.9 million acres) in 1971 (U. S. Dept. of Agriculture,(1972a). Based on these figures, it would appear that at least 25 million lbs. of insecticides must have been used on corn in the corn belt in 1971.

The U. S. Department of Agriculture (1968b, 1970b, 1974) estimates do not include breakdowns of quantities of insecticides by regions, individual crops, and types of insecticides, herbicides and fungicides. However, breakdowns by types of pesticides are given by crops for the nation, and for all crops by regions. Table 16 summarizes the quantities of insecticides by (chemical groups) used on corn in the U. S. (left part of table) and on all farm crops in the corn belt (right part of table), for the years 1964, 1966, 1971.

The five corn belt states (Illinois, Indiana, Iowa, Missouri and Ohio) raised 53% (33.9 million acres) of the total U. S. corn acreage (64.0 million acres) in 1971. Again, the USDA's estimate of the quantity of insecticides used on corn in the entire U.S. in 1971, 25.5 million lbs., appears to be unrealistically low. As pointed out in the preceding paragraphs, there is good reason to believe that at least that quantity of insecticides was used on corn in the corn belt states alone in 1971.

The right part of Table 16 lists all insecticides used on all crops in the corn belt by years and by chemical groups. Again, the quantities at least for 1971 appear to be unrealistically low. The USDA estimates total use of all insecticides on all crops in the 5-state region in 1971 at 18.4 million lbs., whereas other data indicate that more than 25 million lbs. of insecticides were used on corn alone.

Thus, there are some questions regarding the quantitative aspects of these USDA pesticide use estimates. However, the trends that they reflect (both parts of Table 16) agree well with data from other sources, indicating a substantial increase in the use of insecticides on corn in the mid- and late 1960's, and a slowing down or levelling off of this trend beginning about 1970 (see also Tables 13 and 14). The share of chlorinated hydrocarbon insecticides in the total use is declining, with a proportional increase in the use of organic phosphate and carbamate insecticides.

The use of insecticides on corn in Iowa and Illinois during the last three years appears to continue on the same general trend. Table 17 reports the corn insecticide use practices of the Iowa and Illinois corn growers surveyed in this study in 1973 and correlates our findings with the estimates by Petty (1974) and Stockdale (1971, 1973) already cited, and with four other previous surveys (identified in the explanations to Table 17).

These data indicate that during the last four years, 50-60% of the growers in Iowa and Illinois used insecticides on corn, and that roughly the same percentage of the total corn acreage in both states was treated. In our survey of Iowa and Illinois farmers in 1973, it was found that 57% of the corn acres in Iowa and 50% of those in Illinois followed soybeans in the rotation (Table 4). These figures agree well with those in Table 17 and suggest that many growers believe, along with Iowa and Illinois

Table 17: Use of Soil Insecticides on Corn in Iowa and Illinois, 1966 - 1973

Year	Percentage of Growers Using Soil Insecticides on Corn		Percentage of Corn Acres[1/] Treated with Soil Insecticides	
	Iowa	Illinois	Iowa	Illinois
1966				53% (1, 3)
1967				58% (1, 4)
1968				62% (1, 4)
1969				67% (1, 5)
1970	54% (7)	56% (8)		66% (1, 5)
1971			56% (2, 5)	60% (1, 5)
1972	57% (9)	48% (10)		54% (1, 6)
1973	53% (11)	70% (11)	42% (2)	

1/ Corn acres harvested for grain.

Sources:

(1) Petty, 1974. (2) Stockdale, 1971, 1973.
(3) U. S. Dept. of Agriculture, 1968a.
(4) U. S. Dept. of Agriculture, 1970a.
(5) U. S. Dept. of Agriculture, 1972a.
(6) Illinois Cooperative Crop Reporting Service, 1973a,
(7) Wallaces Farmer, 1970; responses from 702 Iowa corn growers.
(8) Prairie Farmer, 1970; responses from 636 Illinois corn growers.
(9) Wallaces Farmer, 1972; responses from 667 Iowa corn growers.
(10) Prairie Farmer, 1972; responses from 608 Illinois corn growers.
(11) This study, 1973; responses from 58 Iowa and 239 Illinois corn growers farming more than 320 acres.

University research and extension entomologists, that corn following soybeans in the rotation rarely requires insecticide treatments.

A list of the major insecticides used on corn in Iowa and Illinois in 1970, 1972 and 1973 is given in Table 18. It is interesting to note that during this four-year period, the use of the chlorinated hydrocarbon insecticides, aldrin and heptachlor, remained essentially unchanged or perhaps even increased slightly in Iowa, whereas their use showed a downtrend in Illinois. These divergent trends in the two states parallel the divergent policies of the Iowa and Illinois extension agencies concerning the need for continued use of chlorinated hydrocarbon insecticides on corn.

The use of organic phosphate insecticides (phorate, diazinon and Dyfonate) is on a slightly increasing trend according to Table 18. Among the carbamates, the use of carbofuran is increasing strongly, while the use of metalkamate seems to be rapidly declining in both states.

Concerning cost of corn insecticides, 50% of the corn insecticide users in both states in our 1973 survey reported that they had experienced a cost increase during the last 5 years; 9% in each state reported a decrease; the remaining respondents felt that costs had remained about the same. Those growers that reported cost increases stated that they ranged from 2 to 200%; the average increase reported was 28% in Iowa, 25% in Illinois.

Most corn soil insecticide users were well satisfied with the effectiveness of the products they used during the last two years. All of the Iowa respondents reported satisfactory or better suppression of insects in both years. Only 4% of the Illinois corn insecticide users felt that control was unsatisfactory in 1973; 8% were dissatisfied in 1972. More than 90% of the corn soil insecticide users in both states felt that their money for these products was well spent. Some 6% of the respondents in both states felt they

Table 18: Use of Major Corn Soil Insecticides in Iowa and Illinois by Products in 1970, 1972 and 1973[1]

Insecticide	Iowa			Illinois		
	1970[2]	1972[3]	1973[6]	1970[4]	1972[5]	1973[6]
	Percent of Corn Soil Insecticide Users[1]					
Aldrin	41	35	49	49	43	32
Heptachlor	17	8	18	25	11	14
Phorate	23	29	30	18	19	18
Diazinon	6	4	negl.	14	21	18
Dyfonate	4	7	6	2	8	13
Carbofuran	4	15	24	4	12	13
Metalkamate (Bux)	38	32	12	10	10	5

1/ Totals do not add up to 100 because minor products are not included, and because many growers used more than one product.

Sources:

2/ Wallaces Farmer, 1970; responses from 377 Iowa corn soil insecticide users.

3/ Wallaces Farmer, 1972; responses from 375 Iowa corn soil insecticide users.

4/ Prairie Farmer, 1970; responses from 341 Illinois corn soil insecticide users.

5/ Prairie Farmer, 1972; responses from 292 Illinois corn soil insecticide users.

6/ This study, 1973; responses from 33 Iowa and 157 Illinois corn soil insecticide users farming more than 320 acres.

should have spent more money for corn insecticides in 1972. In both years, about 6% of the Illinois respondents felt that their money for corn insecticides was wasted, while none of the Iowa respondents felt that way in either year.

D. Side Effects from the Use of Corn Insecticides

The data presented in the preceding sections of this chapter, especially in Tables 14, 15, 16 and 18, document that chlorinated hydrocarbon insecticides have been used extensively in Iowa and Illinois during the last two decades. It is estimated that aldrin accounted for 80 to 90% of the total use of chlorinated hydrocarbon insecticides in the area during that period. Thus, aldrin has been used in both states in much larger quantities cumulatively than any other insecticide.

Aldrin residues are metabolized to its more stable epoxidation product, dieldrin, after application. In the 1969 National Soils Monitoring program for Pesticides (Wiersma et al. 1972), Illinois had the highest aldrin-dieldrin soil residues of any state. Dieldrin residues were found in 61.3% of the 142 samples from the state that were analyzed, ranging from 0.01 - 1.42 ppm; the mean level was 0.11 ppm. Aldrin residues were present in 42.2% of the Illinois samples, ranging from 0.01 - 2.24 ppm; the mean level was 0.13 ppm.

In Iowa, dieldrin residues were found in 53.6% of 151 samples analyzed; they ranged from 0.01 - 0.42 ppm, the mean level was 0.60 ppm. Aldrin residues were present in 31.8% of the Iowa samples, ranging from 0.01 - 1.37 ppm, the mean level was 0.04 ppm.

By comparison, dieldrin residues were found in 27.8% of 1,729 samples collected nationwide; they ranged from 0.01 to 1.60 ppm, and the mean level was 0.03 ppm. Aldrin residues were present in 10.9% of the samples from all states, ranging from 0.01 - 3.06 ppm; the mean level was 0.02 ppm.

In a follow-on study by Carey et al. (1973), 400 soil samples were obtained in 1970 from 12 states in the corn belt region. Illinois again had the highest dieldrin residues among all 12 states included in this survey. Dieldrin residues were found in 66.7% of 69 soil samples from Illinois that were analyzed; they averaged 0.14 ppm, and ranged from 0.01 - 1.08 ppm. In Iowa, dieldrin residues were found in 55.3% of 76 samples analyzed, averaging 0.10 ppm and ranging from 0.01 to 1.03 ppm.

In the same study, Carey et al. also found dieldrin residues in 9.7% of 145 samples of cornstalks, and in 56% of 75 soybean samples that were analyzed. 2.7% of the soybean samples also contained residues of heptachlor epoxide, the metabolite of heptachlor. No heptachlor epoxide residues were found in any of the cornstalk samples. No tolerances have been established for residues of these products in soybeans.

During 1969-70 in Illinois, a total of 27 dairy farms were found to be producing milk containing illegal amounts of chlorinated hydrocarbon insecticide residues and, in 1971, the Illinois Department of Public Health found dieldrin residues approaching an illegal level in a sample of cheese taken from a northern Illinois manufacturer.

Moore et al. (1973) recently reported on a study conducted to determine the sources of this chlorinated hydrocarbon insecticide contamination. They concluded that the chances of dieldrin residues in milk exceeding the administrative guideline of 0.3 ppm (fat basis) were greatest on dairy farms where aldrin soil treatments were applied within the last six or seven years. They predict that additional dairy herds, but in lessening numbers, will be found producing milk with illegal residues for about 4 to 6 more years.

Hay and oat straw were found to supply significant amounts of dieldrin to dairy cattle. In addition, roasted soybeans, a relatively new dairy cattle feed, appeared to be an important potential source of dieldrin contamination. Corn silage, commercial feeds, and well water usually were not important sources of dieldrin contamination. Overall, there was a definite correlation between the dieldrin soil residues on each farm and the level of dieldrin found in the milk.

The Iowa State Cooperative Extension Service warned Iowa dairymen in several news releases during the summer of 1973 against using home-roasted or raw soybeans grown on soil treated with chlorinated hydrocarbon insecticides in dairy rations. It was pointed out that soybeans grown on soil treated with aldrin, heptachlor or chlordane within the last four years may contain residues of these insecticides.

In both Iowa and Illinois, dieldrin residues have also been found in meat animals, poultry, and eggs; and in wildlife, fish, rivers, lakes and streams.

A voluminous literature deals with the problems of residues of aldrin and dieldrin in humans, foods, feeds, and in many elements of the environment including soils, water, air, wildlife, etc., and with their significance. A detailed discussion of these complex problems would be beyond the scope of the present study; suffice it to refer to the comprehensive reviews of the subject by Mrak (1969) and by Pimentel (1971), the latter with special reference to the ecological effects on nontarget species.

Residues of heptachlor, heptachlor epoxide, chlordane and DDT were also found in a relatively high percentage of soil samples from Iowa and Illinois in the studies by Wiersma et al. (1972) and Carey et al. (1973). DDT was used on corn in the midwest against the European corn borer in the past, but that use subsided when resistant corn hybrids became available.

It is thus evident that the heavy use of chlorinated hydrocarbon insecticides, especially aldrin, in Iowa and Illinois has resulted in widespread persistent residues in the environment. How soon actual soil residue levels will reflect the declining use of these chemicals in Illinois remains to be seen. It is well known and documented that due to their persistence, these residues degrade very slowly, and that they bioaccumulate and build up in food chains. The significance of these findings is widely debated, and many divergent opinions have been presented in the course of the current nationwide hearings on aldrin and dieldrin. The detection of dieldrin residues in milk, soybeans and other produce, the resulting bad publicity, adverse reactions on the part of buyers of farm products, and the possibility of legal actions against farm products bearing illegal pesticide residues are probably more real and comprehensible to Iowa and Illinois farmers than the more subtle environmental effects. The actual and potential economic consequences of the widespread presence of these chlorinated hydrocarbon insecticide residues thus have undoubtedly contributed to grower compliance with the Illinois Extension Service's recommendations against the further use of these products. Such compliance is likely to be further encouraged by the widely publicized detection of dieldrin residues in chicken feed in Mississippi and other states that occurred recently.

The development of resistance to aldrin and other chlorinated hydrocarbon insecticides in target insects, another undesirable side effect, has already been covered above in Section C of this Chapter and is mentioned again here only for completeness' sake.

The organic phosphate and carbamate insecticides used on corn have not produced any major undesirable side effects, as far as is known to date. They are generally much less persistent in the soil and in other elements of the environment, and their residues decline during the growing season. They do not biomagnify in food chains. Phorate and carbofuran are highly toxic to humans and other mammals in highly concentrated form. Liquid concentrates of these products require appropriate safety precautions and care in handling, while granular formulations are somewhat less hazardous to operators.

There are indications that some target insects are becoming more difficult to control with organic phosphate or carbamate insecticides.

E. Alternative to Chemical Control of Corn Insects.

In the farmer survey conducted in this project, 53% (31 of 58) of the Iowa respondents and 70% (165 of 237) of those in Illinois used insecticides on corn in 1973. Only slightly more than one-half of the corn insecticide users (18 of 33 in Iowa; 93 of 170 in Illinois) believed that all of their corn acres need insecticide treatments each year, that is only about one-third of all corn growers interviewed. Apparently, the use of corn insecticides is considered essential by a much smaller percentage of growers than the use of herbicides on corn or soybeans (Table 11). Consistent with this finding, 97% of 33 corn insecticide users in Iowa, and 94% of 172 in Illinois would continue to grow corn if no insecticides were available. In reply to the question what they would do in this event to minimize insect damage, responses from 31 Iowa and 150 Illinois farmers were as follows:

	Iowa	Illinois
	% Respondents	
-- Rotate crops	58	65
-- Till and/or cultivate more	19	4
-- Nothing	10	9

Other alternatives, each mentioned by less than 10% of the respondents in either state, included growing fewer acres of corn; planting thicker, later, or resistant varieties; treating seed with livestock dip (!); harvesting earlier; fertilizing more; seeking advice from the university; writing to politicians; and/or praying.

Corn insecticide users in this survey were also asked if they would change their insecticide use patterns if the cost of insecticides were twice as high as what they actually paid. Those respondents (8 = 24% in Iowa; 68 = 40% in Illinois) who answered yes were asked what changes they would make. This question served to find out how growers might reduce their use of insecticides on corn if need be. Replies from 8 Iowa and 66 Illinois respondents were as follows:

	Iowa	Illinois
	% Respondents	
-- Grow fewer acres of corn	38	9
-- Treat fewer acres with insecticide	25	26
-- Change crop rotation	25	9
-- Use lower rate of insecticide	13	21
-- Use insecticide only if and when loss occurs	13	0

Other alternatives mentioned by fewer than 10% of the respondents in either state included using a less expensive product; spraying corn rootworm adults; asking county agent; cultivating more; and/or praying.

As mentioned earlier, only about one-third of all corn growers interviewed in both states felt that all of their corn acres need chemical insecticides each year. Those growers (15 in Iowa; 77 in Illinois) who felt that only some of their corn fields need insecticides were then asked: "How do you decide which corn acres to treat and which not?" Responses from 15 Iowa and from 73 Illinois growers were as follows:

	Iowa	Illinois
	% Respondents	
-- Treat only corn on corn	73	33
-- Treat only corn on sod	20	18
-- Treat all corn acres regardless	20	4
-- Treat only corn on soybeans	0	5
-- Treat only the seed	0	4

Additional responses, each mentioned by only a few respondents, included considering crop history, weather, last year's insect infestation level, neighbors' crops, soil type, etc. One respondent summed up a common dilemma: "Don't know how to tell if I need control chemicals, so I apply to all acres".

No effective, commercially feasible nonchemical methods for the control of soil insects are currently available other than those perceived by the growers themselves, and already practiced by many of them. Substantial research efforts are in progress toward the development of alternative insect control methods, and of integrated insect management programs for corn. Development of better and more reliable diagnostic and predictive methods with a view to the reduction of unnecessary treatments is one important objective.

Other avenues that are currently being pursued by researchers include the use of insect growth regulators, and of microbial agents including Bacillus thuringiensis and nuclear polyhedrosis viruses. However, neither insect growth regulators nor microbial agents have thus far shown much promise for the control of soil insects and thus are not realistic alternatives to the use of chemical insecticides at the present time (Diekman, 1974; Maddox, 1974).

Breeding of resistant corn varieties is another approach being pursued at the research level. Traits being sought include greater plant tolerance to corn rootworm feeding, greater regenerative power of the corn root system, and corn silks that may adversely affect the fecundity and longevity of corn rootworm adults. However, improved corn varieties with one or more of these desirable features are not available to growers as yet.

Both the University of Illinois and Iowa State University participate in a multi-state corn pest management project supported by the U. S. Department of Agriculture and the Environmental Protection Agency. Work under this project was started in 1973.

In Iowa, a pilot scouting program was set up in Hamilton County, in the central part of the State. 25 corn growers participated. Throughout the growing season, one scout made surveys of wireworm, cutworm, European corn borer, corn rootworm, aphid, and beneficial insect populations. All populations surveyed were determined to be below economic thresholds. Consequently, no control measures were recommended or applied. In addition, weeds were surveyed twice during the growing season, the first time in June to determine approximate levels of herbicide efficiency, the second time in July. Soil samples were taken from the project area to be analyzed for pesticide residues, and plans were made for a data storage and retrieval system (Hintz et al. 1973).

For 1974, Iowa plans to continue the program in Hamilton County, and to add a survey of green cloverworms in soybeans. In addition, surveys are to be started in Henry and Lee Counties on corn, soybeans (green cloverworms) and alfalfa (alfalfa weevil).

Similar efforts are in progress in Illinois (Luckmann et al. 1974).

F. Summary.

Corn in Iowa and Illinois is attacked by three species of the corn rootworm (at least two of them resistant against chlorinated hydrocarbon insecticides); by a complex of additional soil insects; and by some foliar insects. The foliar insects are economically much less important than the soil insects.

Soil insecticides are currently used on 50 to 60% of all corn acres in Iowa and Illinois. This use has declined somewhat from a peak in 1969/1970. It is estimated that more than one-half of the corn acres currently being treated with soil insecticides do not need the treatment. However, diagnostic and predictive methods available to growers are not adequate, and it is often difficult for them to decide whether or not to treat. Thus, this insecticide use appears to be a partially wasteful practice from the overall standpoint while to many individual growers, it is a necessary protective measure. According to estimates by Illinois entomologists, Illinois corn growers realized cumulative net profits from the use of corn soil insecticides of the order of about $250 million during the ten year period, 1964-1973.

Until about 1970, chlorinated hydrocarbon insecticides (80-90% aldrin) were used on about two-thirds of all corn acres treated with soil insecticides. Since that time, the less persistent organic phosphate and carbamate insecticides have increasingly replaced chlorinated hydrocarbons. The latter presently account for almost two-thirds of the total corn acreage treated with soil insecticides in the two states.

Aldrin residues (including dieldrin, a principal metabolite of aldrin) were found in a high percentage (54 to 67%) of soil samples from Iowa and Illinois. Aldrin/dieldrin residues have also been found in milk, meat, poultry, eggs and soybeans produced in the area, as well as in wildlife, fish, rivers, lakes and streams.

A number of target insects have developed varying degrees of resistance to chlorinated hydrocarbon insecticides. The organic phosphate and carbamate insecticides used on corn have not produced any major undesirable side effects to date, as far as is known, except for the development of resistance in target insects in some instances.

Among the farmers surveyed in this study, 53% of the Iowa respondents and 70% of those in Illinois used corn insecticides in 1973. Only slightly more than one-half of the corn insecticide users in both states, that is only about one-third of all corn growers interviewed, believed that all of their corn acres need insecticide treatments each year. Consistent with this finding, 97% of the corn insecticide users in Iowa and 94% of those in Illinois would continue to grow corn if no insecticides were available.

Crop rotation is the most effective currently available nonchemical method to suppress corn soil insects. However, growers' crop rotation decisions are governed primarily by factors other than crop protection considerations. No effective, commercially feasible nonchemical methods for the control of corn soil insects are currently available. Substantial research efforts are in progress toward the development of better corn insect prediction and control methods, and of integrated insect management systems, but these have not been perfected at the grower level as yet.

VI. SOYBEAN INSECTS

Until recently, soybeans had fewer economically important insect problems than most other field crops. For instance, the widely used textbook on insects by Metcalf, Flint and Metcalf (1962) contains a little more than one page of text on soybean and cowpea insects, compared to 58 pages on insects injurious to corn.

Soil insects are generally not a problem on soybeans. Foliar insects, especially the green cloverworm, *Plathypena scabra*, build up to serious proportions on soybeans in the midwest only occasionally, last in 1966 and 1968. However, 1973 was another such year, and green cloverworms caused considerable concern to entomologists as well as to soybean growers in Iowa and Illinois. Randell et al. (1974) estimate that about 736,000 acres of soybeans in Illinois were treated against this insect in 1973, and that growers realized a profit of $1.1 million above the cost of treatment from using insecticides (Table 12).

The Illinois insect control recommendations for 1973 advised treating against the green cloverworm when 6 or more worms per foot of row are present. As the 1973 growing season progressed, soybean prices skyrocketed (Table 8). In its "Insect, Weed and Plant Disease Survey Bulletin" that is issued weekly during the growing season, the Illinois Extension Service advised on July 20, 1973 (No. 18, page 3):

> "Normally, 6 (green clover) worms per foot of row are considered damaging. We will reduce that to 3 or 4 this year."

This recommendation was reiterated in subsequent issues of Illinois' Insect, Weed and Plant Disease Survey Bulletin.

By contrast, Iowa's "Insect Pest Control Recommendations for 1973", IC-328 (Rev.), February, 1973, contained the following advice on the control of soybean insects:

> "The importance of treatment for the insects listed (bean leaf beetle, green cloverworm, thistle caterpillar, garden webworm, grasshopper) depends on the number of insects present and the stage of growth of the soybeans. At Stage 7 (pods filling) 50% defoliation reduces yield 18%. A population of 10 grasshoppers per square yard in field edges will defoliate beans completely; 20 to 25 green cloverworms per linear foot of row will cause 25 to 30% defoliation."

The Iowa Insect, Weed and Plant Disease Newsletter of July 23, 1973, IC-405(12) stated that the economic injury level of green cloverworms (when yields are reduced by more than the cost of treatment) is 18 to 20 worms per foot of row at Stage 7 (pod fill) of the soybeans, based on experimental data. Growers were further advised that green cloverworm populations are subject to parasites, predators and weather conditions.

In the Newsletter of August 20, 1973, IC-405(16), a treatment threshold of 15 to 20 green cloverworms per foot of row was reiterated, along with the statement:

> "Green cloverworms are parasitized by wasp and fly parasites and also victimized by insect pathogens so treatment of fields at subeconomic levels not only wastes money, it also slows the buildup of these natural control agents."

Not surprisingly, pesticide salesmen made more use of the Illinois than of the Iowa soybean insect control recommendations. Their efforts received considerable support from the fact that an insecticide treatment costs only $2.00 - 3.00/acre (including cost of application), equal to the value of less than one-half bushel of soybeans during the summer of 1973 (Tables 8, 10).

Recent experiences in southeastern and southern soybean growing areas of the U. S. indicate that increased use of insecticides on soybeans may well lead to progressive destruction of natural control factors, need for more insecticides, etc. An effective insect management program for soybeans would thus seem to be most desirable for the midwest at this time where this development has not started as yet.

VII. CORN WEEDS

A. Major Weeds

In the midwest, several major weeds compete with corn for water, nutrients, sunlight, and other growth factors, and threaten to reduce yields, interfere with planting, tilling and harvesting operations, and result in the further propagation of weeds through the spreading of weed seeds. Table 19 lists the five most important corn weeds in Iowa and Illinois by percent of the total corn acreage infested, based on information provided by Federal and State weed specialists in a nationwide survey on weeds conducted in 1968 (U. S. Dept. of Agriculture, 1972b).

Foxtails, velvetleaf and smartweed were considered serious corn weeds in both states. Fall panicum and nutsedge rated among the five most important weeds only in Illinois, and cocklebur and sunflower only in Iowa.

B. Losses Due to Corn Weeds and Benefits from Their Control

Weed scientists in Iowa and Illinois estimate that weeds reduce corn yields by up to 10 bu./acre in many "ordinary", not catastrophically weedy fields.

Slife (1973) studied annual net profits from the use of herbicides as compared to cultural practices for continuous corn, and for different corn rotations over a 6-year period, 1966 to 1971. Table 20 summarizes Slife's results for continuous corn. The treatments compared were (1) broadcast application of the same herbicide (atrazine) each year with one cultivation, (2) broadcast application of a different herbicide each year with one cultivation, and (3) no herbicide with three timely cultivations. Cost figures per acre were assigned to each crop for all production and harvesting operations. Each cultivation was charged at the rate of $1.50/acre.

Table 19 : Five Most Important Corn Weeds in Iowa and Illinois, 1968

Weeds	Percent of Total Soybean Acreage Infested	
	Iowa	Illinois
Giant foxtail, *Setaria faberi*	1/	50%
Foxtails, *Setaria* spp.	90%	1/
Smartweed, *Polygonum* spp.	50%	25%
Velvetleaf, *Abutilon theophrasti*	60%	25%
Fall panicum, *Panicum dichotomiflorum*	2/	15%
Nutsedge, *Cyperus* spp.	2/	10%
Cocklebur, *Xanthium* spp.	50%	2/
Sunflower, *Helianthus* spp.	10%	2/

1/ Not available.

2/ Not included among five most important problem weeds in the state.

Source: U. S. Department of Agriculture, 1972b.

Table 20 : Average Annual Costs and Returns from Different Methods of Controlling Weeds in Continuous Corn in Illinois Over a Six-Year Period, 1966 - 1971

Average Annual Costs and Returns Per Acre	Atrazine Plus One Cultivation	Different Herbicide Plus One Cultivation	No Herbicide, Three Cultivations
Cost of production except weed control	$ 90.13	$ 90.13	$ 90.13
Cost of cultivation(s)	1.50	1.50	4.50
Cost of herbicide	8.43	8.93	--
Cost of herbicide application	1.50	1.50	--
Total average production cost	101.56	102.06	94.63
Total average gross return	130.76	136.47	102.94
Total average net return	29.20	34.41	8.31

Source: Adapted from Slife (1973).

Each of the herbicide treatments were charged with one cultivation, the cost of the herbicide, and the cost of application of the herbicide ($1.50/acre). The figures reported in Table 20 are the average net returns per acre under the three weed control systems over the 6-year period.

In 1967 and in 1969, the corn plots treated with herbicide produced enough net income over the plots receiving cultivation only to just cover the cost of the herbicide and its application, but no more. In these two years, the cultivated plots did not suffer great yield reductions because weeds were adequately removed by cultivation only. In the other four years, cultivation alone did not control weeds sufficiently, and yield reductions were substantial.

Slife concludes from these results that over the 6-year period covered by his study, three timely cultivations were generally not adequate to prevent yield reduction from weeds, and that there is a direct economic return from the use of herbicides on corn whenever moderate or heavier infestations of weeds can be expected. Rotation of herbicides was more advantageous than the continuous use of atrazine.

Slife's 6-year experiment also included a corn-corn-soybeans and a corn-soybeans-wheat rotation. Average net return data were obtained in the same manner as described for the continuous corn. For the corn-corn-soybeans rotation, the average net returns per acre were $49.01 for the same herbicide plus one cultivation; $55.62 for a different herbicide each year plus one cultivation; and $35.46 for three cultivations without herbicide.

For the corn-soybeans-wheat rotation, average net returns per acre were $40.77 for the same herbicide plus one cultivation; $45.47 for a different herbicide each year plus one cultivation; and $33.82 for three cultivations without herbicide.

All of these dollar returns from weed control were computed on the basis of farm prices for corn that prevailed during the period when the tests were conducted. These returns would, of course, be even greater in terms of the corn prices of 1972 and 1973 because the costs of producing corn and of corn herbicides have not increased nearly as much as the average corn prices received by farmers, which doubled from 1971 to 1973 (Table 1).

The Iowa and Illinois corn herbicide users interviewed in this study in 1973 were asked what benefits they obtain from the use of herbicides. Replies from 58 Iowa and 230 Illinois respondents to seven check-off-type questions were as follows:

	Iowa	Illinois
	% Respondents	
-- Control weeds	100	96
-- Save cultivating	95	70
-- Good-looking fields	93	52
-- Save labor	78	65
-- Save tilling operations other than cultivating	2	9
-- Facilitate planting	0	8
-- No benefits	0	0

Additional, unstructured write-in replies under "additional benefits" included the following, in decreasing order of frequency mentioned: Increased yield; facilitates harvesting, sleep sounder; saves time; prevents spreading of weeds; facilitates fall plowing; controls erosion; produce weed-free seed.

It is thus apparent that growers believe that they derive substantial benefits from the use of herbicides on corn.

C. Use Patterns of Herbicides on Corn

The use of herbicides on corn in the five corn belt states (Illinois, Indiana, Iowa, Missouri, and Ohio) increased from 12.6 million lbs. in 1964 to 27.5 million lbs. in 1966 (increase of 118%), and to 54.1 million lbs. in 1971 (increase of 97% from 1966), according to the U. S. Department of Agriculture (1968b, 1970b, 1974. Thus, the quantities of herbicides used on corn in this area more than quadrupled during the 8-year period, 1964-1971 (Table 9).

In the survey of Iowa and Illinois farmers conducted in this study, all of the Iowa corn growers and 99% of the Illinois corn growers reported that they used herbicides on corn in 1973. Additional data on the use of herbicides on corn in the two states are available from surveys conducted by two farm magazines in 1970 and in 1972.

Wallaces Farmer (1970, 1972) surveyed Iowa corn growers. Of the respondents who raised 100 acres or more of corn, 96% of 287 respondents in 1970, and the same percentage of 212 respondents in 1972 used herbicides. In the same surveys, 77% of the total corn acreage of 696 respondents was treated with chemical herbicides in 1970, and 79% of the total corn acreage of 653 respondents in 1972.

In a survey of Illinois corn growers by Prairie Farmer (1970, 1972), 97% of 306 growers who raised more than 100 acres of corn in 1970, and also 97% of 289 growers who raised more than 100 acres of corn in 1972 used herbicides. In the same surveys, 85% of the total corn acreage of 633 respondents was treated with herbicides in 1970, and 89% of the total corn acreage of 608 growers in 1972.

According to these findings, more than 95% of the larger corn growers in both states use chemical herbicides, and between

80 and 90% of all corn acres in Iowa and Illinois are treated with chemical herbicides. Since some corn acres receive both pre- and postemergence treatments (Illinois Cooperative Crop Reporting Service, 1973b, U. S. Dept. of Agriculture, 1972b), the number of "gross" corn acres (acres treated more than once counted for each treatment) considerably exceeds the number of total corn acres harvested.

Table 21 summarizes the use of major individual corn herbicides in Iowa and Illinois in 1970, 1972 and 1973, as derived from the farmer survey conducted in this project, and from Wallaces Farmer's and Prairie Farmer's 1970 and 1972 surveys. All three surveys indicate that atrazine is the most frequently used corn herbicide in both states. In 1973, the two triazine herbicides, atrazine and cyanazine, combined were used by more than 80% of the Iowa corn growers interviewed, and by almost 70% of their counterparts in Illinois. The two anilide herbicides, propachlor and alachlor, were also used heavily in both states. Butylate, a thiocarbamate herbicide, was first introduced in the late 1960's and has rapidly increased in volume in Iowa and Illinois during the last four years. 2,4-D continues to be used by about one-third of the corn growers in both states, primarily as a postemergence treatment against broadleaf weeds.

In our 1973 farmer survey, 97% of the Iowa and 94% of the Illinois corn herbicide users considered efficacy of these products during the last two years satisfactory or better. None of the Iowa respondents, and only 2.2% (3.6% in 1972) of the Illinois respondents felt that the money they spent for corn herbicides was wasted. About 10% of the respondents from both states felt that they should have spent more money for corn herbicides in 1972 and 1973. The great majority of all corn herbicide users in both states (about 90%) felt that their money for corn herbicides was well spent in both years.

Table 21: Use of Major Corn Herbicides in Iowa and Illinois by Products in 1970, 1972 and 1973

Herbicide	Iowa			Illinois		
	1970[2]	1972[3]	1973[6]	1970[4]	1972[5]	1973[6]
	Percent of Corn Herbicide Users[1]					
Atrazine	48	61	62	60	59	60
Cyanazine	negl.	5	21	negl.	2	8
Propachlor	33	29	40	38	29	43
Alachlor	6	21	17	6	22	20
Butylate	4	8	33	8	15	34
2,4-D	43	29	33	27	22	33

1/ Totals do not add up to 100 because minor products are not included in this table, and because many growers used more than one product.

Sources:

2/ Wallaces Farmer, 1970; responses from 610 Iowa corn herbicide users.

3/ Wallaces Farmer, 1972; responses from 552 Iowa corn herbicide users.

4/ Prairie Farmer; 1970; responses from 537 Illinois corn herbicide users.

5/ Prairie Farmer, 1972; responses from 523 Illinois corn herbicide users.

6/ This study, 1973; responses from 58 Iowa and 217 Illinois corn herbicide users farming more than 320 acres.

About 69% of the Iowa corn herbicide users (40 of 58), and 42% of those in Illinois (95 of 228) changed products at least once since 1970. Those that did were asked why. The following reasons were given by 40 Iowa and 88 Illinois respondents:

	Iowa	Illinois
	% Respondents	
-- Want to increase spectrum of weed control	20	66
-- Concerned about carryover of herbicide residues	35	9
-- Change to broadcast application	18	6
-- Weather	15	5
-- Changed to preplant application	8	0
-- Cost of herbicide	3	5
-- Change of, or difficulty with equipment	3	5

Almost two-thirds of the corn herbicide users in both states reported that their cost ($ per acre) for corn herbicides had increased during the last five years; 5% of the respondents reported a cost decrease; the remainder felt that the cost of herbicides had remained about the same. Reported increases in the cost of corn herbicides ranged from 5 - 100% in Iowa, from 3 - 400% in Illinois, averaging 23% in Iowa, 38% in Illinois.

A high percentage of the corn herbicide users in both states (88% = 51 of 58 in Iowa; 82% = 189 of 230 in Illinois) believe that all of their corn acres need herbicide treatments each year. Of those who did not think so, about 60% (3 of 5 in Iowa; 24 of 41 in Illinois) stated that they treat only the weedy areas, whereas the remainder treat all acres regardless.

Most of the corn herbicide users (93% = 5o of 54 in Iowa; 95% = 211 of 223 in Illinois) feel that the corn herbicides available today give better weed control than those they used ten years ago. 62% (36 of 58) of the Iowa growers and 56% (127 of 226) of those in Illinois would not change their herbicide use patterns if the cost of herbicides would double. 97% of the corn growers in both states (56 of 58 in Iowa; 219 of 226 in Illinois) would continue to grown corn if no herbicides were available. Among those few that would not grow corn without herbicides, some stated they would grow grass, wheat, soybeans and/or oats instead, some said they would retire.

D. Side Effects from the Use of Herbicides on Corn

The heavy use of herbicides, especially the relatively persistent product atrazine, in Iowa and Illinois has resulted in increasing evidence of persistence of herbicide residues in the soil. In the nationwide survey of weed scientists conducted by the USDA in 1968, both Iowa and Illinois answered "Yes" to the question whether they had a herbicide persistence problem. Illinois reported 2%, Iowa 20% of the herbicide-treated corn acreage affected (U. S. Department of Agriculture, 1972b).

No more recent data are available on this problem. However, since the use of corn herbicides, especially atrazine, has continued to increase in the interim, the persistence problem most likely has also. In the 1973 farmer survey, 70% of the Iowa corn herbicide users and 42% of those in Illinois changed products at least once since 1970. Concern about residue carryover was the second most important reason given (by 35% of the Iowa and 9% of the Illinois respondents).

In the National Soils Monitoring Program for Pesticides, 1,729 samples of cropland soils were collected from 43 states in 1969. Samples were analyzed for residues of atrazine only when pesticide use records indicated that this herbicide had been applied. Atrazine residues were found in 2 samples out of 43 (4.7%) from Illinois, and in 13 of 48 samples (27.1%) from Iowa. Residues found ranged from 0.02 - 0.10 ppm (mean level less than 0.01 ppm) in Illinois, and 0.01 - 1.55 ppm (mean level 0.05 ppm) in Iowa (G. B. Wiersma et al. 1972). The report does not indicate whether atrazine metabolites were included in these analyses, or whether the analytical method employed registered only the parent compound.

Soil residues of atrazine prevent growing of sensitive crops following atrazine-treated corn in rotation. This is especially true if atrazine has been used by itself at the full recommended rate. Soybeans and oats are particularly sensitive to atrazine and have sometimes been affected even in the second year after atrazine use.

It is noteworthy that all three sources quoted on the corn herbicide persistence problem, i.e., the 1968 USDA survey, the 1969 National Soils Monitoring Program for Pesticides, and our 1973 survey of farmers, indicate that the problem appears to be greater in Iowa than in Illinois. This is not surprising since Iowa grows more acres of corn than Illinois (Table 3) and therefore has probably had heavier cumulative inputs of persistent corn herbicides than Illinois.

Cyanazine, while also a triazine chemical, is considerably less persistent than atrazine and has, mainly for this reason, increased in use, especially in Iowa, since its introduction a few years ago (Table 21). However, its safety margin on corn is not as good as that of atrazine.

No major persistence problems are known to be associated with the use of any of the other major corn herbicides.

2,4-D may cause damage to susceptible crops or plants (soybeans, cotton, many vegetables, etc.) outside of the target area through spray drift, or if volatile forms of the product are used.

Development of resistance of corn weeds to chemical herbicides has not generally been a problem to this date. However, weed species that are more difficult to control are gradually becoming more predominant as those species that are easily controlled recede. Fall panicum, for instance, has become more abundant in Iowa and Illinois corn fields in recent years.

E. Alternatives to Chemical Control of Corn Weeds

In the survey of farmers conducted in this project in 1973, 97% of the corn herbicide users both in Iowa and Illinois indicated that they would continue to grow corn if no chemical herbicides were available. In reply to the question what they would do to control weeds in this event, replies from 56 Iowa and 212 Illinois respondents were as follows:

	Iowa	Illinois
	% Respondents	
-- Till and/or cultivate more	89	98
-- Rotate crops	25	10
-- Grow fewer acres of corn	16	5
-- Hoe and pull weeds by hand	7	11
-- Change planting time	5	9
-- "Check row" (cultivate between rows and at 90 degree angle)	7	2

Other alternatives mentioned less frequently included "fight, fight, fight"; "work like hell"; "raise hell"; "no way"; or simply "don't know".

Corn growers were also asked if they would change their corn herbicide use practices if the cost of herbicides were twice as high. Those respondents (38% = 22 of 58 in Iowa; 44% = 99 of 226 in Illinois) who said yes were asked what they would do. The answers to this question indicate what possibilities growers see to reduce use of herbicides on corn. Replies from 22 Iowa and 97 Illinois respondents were as follows:

	Iowa	Illinois
	% Respondents	
-- Cultivate more	50	43
-- Reduce corn acres	36	6
-- Use lower rate of herbicide	14	13
-- Band herbicide rather than broadcast	14	8
-- Treat fewer acres with herbicide	5	26

Less than 5% of the respondents mentioned changing crop rotation; changing planting date; changing corn variety; or being undecided.

University weed scientists, extension specialists and farmers agree that none of these nonchemical alternatives would be comparable to herbicides in regard to cost, effectiveness, efficiency, profitability and convenience.

F. Summary

Major corn weeds in the midwest include foxtails, velvetleaf, smartweed, cocklebur, fall panicum, nutsedge, and wild sunflower. Weed scientists in Iowa and Illinois estimate that weeds reduce corn yields by up to 10 bu./acre in many average, not catastrophically weedy fields. Research data widely publicized and accepted in the midwest indicate that over a six-year period, three timely cultivations per year were not adequate to prevent corn yield reduction from weeds, and that the use of herbicides on corn is profitable whenever moderate or heavier weed infestations can be expected.

The use of herbicides saves cultivating and labor and facilitates harvesting. All of the Iowa corn growers and 99% of those in Illinois interviewed in this study used corn herbicides in 1973. Between 80 and 90% of all corn acres in Iowa and Illinois are treated with chemical herbicides. Some of these acres receive both pre- and postemergence treatments. The most frequently used corn herbicides were atrazine and propachlor.

A high percentage of the corn herbicide users in both states (88% in Iowa, 82% in Illinois) believe that all of their corn acres need herbicide treatments each year. However, almost all (97%) of the corn growers in both states would continue to grow corn if no herbicides were available.

Currently available monitoring data are not adequate to evaluate whether and to what extent corn herbicide residues may be building up in heavily treated soils. In a nationwide survey of weed scientists in 1968, both Iowa and Illinois reported that they had a corn herbicide persistence problem. Illinois reported 2%, Iowa 20% of the herbicide-treated corn acreage affected. In the 1973 farmer survey conducted in this project, concern about residue carryover was expressed by a number of corn herbicide users.

Development of resistance of corn weeds to chemical herbicides has not been a problem to date. However, corn weed populations are gradually changing; more difficult-to-control weeds such as fall panicum are becoming more prevalent as those species that are easily controlled recede.

Growers are familiar with a number of alternatives to chemical weed control, mainly increased cultivation and/or crop rotation. None of these are considered nearly as attractive as herbicides in regard to efficacy, convenience, and profitability by growers or weed specialists.

SOYBEAN WEEDS

VIII.

A. Major Weeds

Table 22 lists the five most important species of weeds infesting soybeans in Iowa and Illinois, based on a nationwide survey of state weed scientists and extension personnel conducted in 1968 (U. S. Department of Agriculture, 1972b). According to this survey, cocklebur and wild sunflower were considered serious and believed to infest about 50% of the total soybean acreage in Iowa. In Illinois, these two species did not rate among the five most important weeds. Conversely, pigweed and morningglory were considered serious in Illinois, but not in Iowa. Foxtails, velvetleaf and smartweed were among the five most important weeds in both states.

Comparing this list against that of the five most important corn weeds from the same survey (Table 19), it is evident that most of the major weeds were common to both corn and soybeans. Exceptions were fall panicum and nutsedge that were listed as serious only in corn; and pigweed and morningglory that were considered serious only in soybeans.

A comprehensive nationwide survey of yield losses due to soybean weeds was conducted in 1970 and again in 1971 under the sponsorship of the basic producer of one of the major soybean herbicides. According to this source, the following five weed species

Table 22 : Five Most Important Soybean Weeds in Iowa and Illinois, 1968

Weeds	Percent of Total Soybean Acreage Infested	
	Iowa	Illinois
Giant foxtail, Setaria faberi	1/	60
Foxtails, Setaria spp.	50	1/
Cocklebur, Xanthium spp.	50	2/
Velvetleaf, Abutilon theophrasti	30	30
Smartweed, Polygonum spp.	20	25
Sunflower, Helianthus spp.	50	2/
Pigweed, Amaranthus spp.	2/	30
Morningglory, Ipomoea spp.	2/	25

1/ Not available.

2/ Not included among five most important problem weeds in the state.

Source: U. S. Department of Agriculture, 1972b.

were most damaging in Iowa (listed in decreasing order of loss caused): foxtail, pigweed, velvetleaf, smartweed, volunteer corn. In Illinois, the five most damaging soybean weeds were foxtail, pigweed, velvetleaf, smartweed, and ragweed.

These two soybean weed surveys thus are in good agreement in regard to the weed species that are economically most damaging to the production of soybeans in Iowa and Illinois.

B. Losses Due to Soybean Weeds and Benefits from Their Control

Soybean plots were included in the 6-year studies conducted by Slife (1973) in Illinois. Slife's plot design and the methods by which he arrived at the total average net return for the different treatments are described in the section on corn weeds, pp. 69, 72, and will not be reiterated here.

Table 23 summarizes the average annual costs and gross and net returns from three different methods of controlling weeds in soybeans over a 6-year period, 1966 - 1971. Best results ($64.10 net return/acre) were achieved when a different soybean herbicide was used each year, along with one cultivation. Annual use of the same herbicide, chloramben, plus one cultivation yielded the next best return, $58.25/acre; whereas three timely cultivations without a chemical herbicide yielded an average net return of $47.86/acre. The use of herbicides on soybeans was unprofitable only in 1969, that is only one out of the six years studied.

Again, as in the case of the corn tests, the returns for the different weed control methods are based on the commodity prices that prevailed at the time. These returns would be greater for all treatments, and the differences in terms of dollars per acre between treatments would be greater, based on the greatly increased soybean prices that growers realized in 1972 and 1973 (Table 1).

Table 23: Average Annual Costs and Returns from Different Methods of Controlling Weeds in Soybeans in Illinois Over a Six-Year Period, 1966 - 1971

Average Annual Costs and Returns Per Acre	Chloramben Plus One Cultivation	Different Herbicide Plus One Cultivation	No Herbicide, Three Cultivations
Cost of production except weed control	$ 51.00	$ 51.00	$ 51.00
Cost of cultivation(s)	1.50	1.50	4.50
Cost of herbicide	13.95	7.29	--
Cost of herbicide application	1.50	1.50	--
Total average production cost	67.95	61.29	55.50
Total average gross return	126.20	125.39	103.36
Total average net return	58.25	64.10	47.86

Source: Adapted from Slife (1973)

In the soybean weed loss surveys conducted in 1970 and 1971 already mentioned in Sec. A above, weed losses were estimated in 26 soybean growing states by a field rating system using a weed loss chart. Five weed loss categories were established on the basis of a large number of research studies in many soybean growing states. In late August, 60 two-man survey teams rated weed infestation levels in a total of 21,000 soybean fields. The five weed loss categories are as follows:

1 - Fields free of weeds, or with only very few weeds - no measurable losses;

2 - Slightly weedy - fields will usually suffer between 5 and 10% yield reduction;

3 - Moderately weedy - fields will yield 10 to 20% less than weed-free fields growing under the same conditions;

4 - Heavy weeds - fields will suffer yield losses of 20 to 35%;

5 - Disaster - fields where soybeans are totally dominated by weeds will suffer yield losses ranging from 35 to 100%.

Table 24 presents the results of the 1971 survey for the United States, and for Iowa and Illinois. The percentage of soybean fields in each of the five weed infestation categories from the 1970 survey are included for comparison.

According to these estimates, the nationwide soybean yield losses due to weeds in 1971 amounted to $428 million. Iowa losses were $45 million, Illinois $71 million. In both states, the heaviest losses were attributed to a relatively large share of fields in loss categories 2 and 3. In addition, Illinois in 1971 had a higher percentage of fields in categories 4 and 5 and, since its total soybean acreage was greater, it had a greater total loss.

Table 25 summarizes results of the 1970 and 1971 soybean weed loss surveys in terms of percent of all soybean fields suffering 5% or more yield loss; average percent loss in all fields; and average

Table 24: Weed Losses in Soybeans in the U.S. and in Iowa and Illinois, 1970 and 1971

Degree of Loss	1971					1970
	Number of Fields	Percent of Fields Surveyed	Acreage in Each Category (000)	Average Loss Per Acre $	Value of Loss $ 000	Percent of Fields Surveyed
United States						
1	4,412	21%	8,994	--	--	29%
2	7,353	35%	14,991	5.82	87,545	26%
3	5,421	26%	11,136	11.64	130,321	27%
4	2,803	13%	5,568	21.61	120,922	13%
5	1,138	5%	2,142	41.55	89,379	5%
Totals	21,127		42,830		$428,167	
Iowa						
1	766	27%	1,496	--	--	35%
2	1,183	43%	2,382	6.72	16,008	29%
3	630	23%	1,274	13.44	17,125	23%
4	183	6%	366	24.96	9,126	10%
5	31	1%	61	48.00	2,925	3%
Totals	2,793		5,540		45,185	
Illinois						
1	843	24%	1,730	--	--	36%
2	1,379	39%	2,811	6.72	18,891	28%
3	858	25%	1,802	13.44	24,219	24%
4	286	8%	577	24.96	14,393	9%
5	137	4%	288	48.00	13,839	3%
Totals	3,503		7,208		71,342	

Source: 1971 National Soybean Weed Loss Survey
Inter/Agriculture
Chicago, Ill.

Table 25 : Summary of Soybean Weed Losses in the U.S. and in Illinois and Iowa, 1970 and 1971

Type of Loss	United States		Iowa		Illinois	
	1970	1971	1970	1971	1970	1971
Fields suffering 5% or more loss	71%	79%	65%	73%	64%	76%
Average % yield loss in all fields	11.5%	12%	9.3%	8.3%	9.2%	10.3%
Average loss						
bu./acre	3.1	3.3	3.0	2.9	2.9	3.3
$/acre	7.75	9.99	7.50	8.65	7.25	9.89

Source: 1971 National Soybean Weed Loss Survey
Inter/Agriculture
Chicago, Illinois

losses in terms of bu./acre and $/acre. These losses occurred in spite of soybean weed control methods available and practiced by soybean growers in 1970 and 1971. The somewhat greater losses in the U. S. and in Illinois in 1971 as compared to 1970 are attributed to wet weather in 1971 which hampered weed control efforts and stimulated heavy weed germination and growth in many areas. The dollar loss figures are greater for 1971 because the 1971 soybean crop was valued at $3.00/bu. for purposes of this survey, the 1970 crop at $2.50/bu.

The results of this survey for Iowa and Illinois agree well with those reported by Slife (1973), as discussed above. In Slife's 6-year studies (Table 23), the use of a soybean herbicide with one cultivation increased average net returns from $10.39 to $16.24/acre over the return from soybeans that received only 3 timely cultivations for weed control, but no herbicide.

The National Soybean Weed Loss Survey (1971) also included a state-by-state weed census, an effort to break down the losses by major weeds for each state. In Iowa and Illinois, the same four weed species accounted for 76% (Illinois) and 87% (Iowa) of the total estimated weed losses. These weeds, and the dollar loss attributed to each, are as follows:

	Illinois	Iowa
	Estimated Loss/State in $000	
Foxtail	23,777	14,725
Pigweed	13,524	10,007
Velvetleaf	9,110	7,102
Smartweed	7,483	7,477
Subtotals	53,894	39,311
All other weeds	17,106	5,689
All weeds	71,000	45,000
First four weeds/total	76%	87%

These data indicate that weeds caused substantial economic losses to soybean growers in Iowa and Illinois (as well as in the entire nation) in 1970 and 1971. Foxtails, pigweed, velvetleaf and smartweed were the four most damaging weeds in Iowa and Illinois.

C. Use Patterns of Herbicides on Soybeans

The use of herbicides on soybeans in the five corn belt states (Illinois, Indiana, Iowa, Missouri, and Ohio) increased from 3.0 million lbs. in 1964 to 6.6 million lbs. in 1966 (increase of 117%), and to 18.9 million lbs. in 1971 (increase of 187% from 1966), according to the U. S. Department of Agriculture (1968b, 1970b, 1974). These estimates indicate that the quantities of herbicides used on soybeans in the corn belt increased more than six-fold during this eight-year period.

In the survey of Iowa and Illinois farmers conducted in this study, 98% of the soybean growers in both states reported using herbicides on soybeans in 1973. As in the case of corn herbicides, results of two previous surveys are available for comparison.

Wallaces Farmer (1970, 1972) surveyed the extent of the use of herbicides on soybeans by Iowa farmers raising 100 acres or more of soybeans. In 1970, 88% of 148 respondents used herbicides, 96% of 140 respondents in 1972. In the same surveys, 71% of the total soybean acreage of 546 respondents was treated with chemical herbicides in 1970, and 79% of the total soybean acreage of 505 respondents in 1972.

In a parallel survey of Illinois soybean growers by Prairie Farmer (1970, 1972), 89% of 237 soybean growers raising more than 100 acres of soybeans used herbicides in 1970, and 94% of 227 such growers in 1972. 73% of the total soybean acreage of 523 respondents was treated with herbicides in 1970, and 85% of the total soybean acreage of 541 respondents in 1972.

Table 26: Use of Major Soybean Herbicides in Iowa and Illinois by Products in 1970, 1972 and 1973.

Herbicide	Iowa			Illinois		
	1970 2/	1972 3/	1973 6/	1970 4/	1972 5/	1973 6/
	Percent of Soybean Herbicide Users 1/					
Trifluralin	37	40	62	30	34	59
Chloramben	48	44	42	52	42	53
Alachlor	16	22	26	18	29	20
Chlorpropham	5	5	9	3	2	5
Metribuzin	-	-	7	-	-	7
Linuron	2	4	4	9	19	11
Vernolate	-	2	2	5	5	11

1/ Totals do not add up to 100 because minor products are not included in this table, and because many growers used more than one product.

Sources:

2/ Wallaces Farmer, 1970; responses from 396 Iowa soybean herbicide users.

3/ Wallaces Farmer, 1972; responses from 400 Iowa soybean herbicide users.

4/ Prairie Farmer, 1970; responses from 391 Illinois soybean herbicide users.

5/ Prairie Farmer, 1972; responses from 454 Illinois soybean herbicide users.

6/ This study,1973; responses from 55 Iowa and 213 Illinois soybean herbicide users farming more than 320 acres.

The findings from these five surveys indicate that 80 to 85% of the total soybean acreage in Iowa and Illinois is treated with chemical herbicides, and that almost all larger soybean growers use chemical herbicides and treat close to 90% of their soybean acreage.

Table 26 combines the results of the surveys by Wallaces Farmer, Prairie Farmer and this project in regard to the most frequently used soybean herbicides. Two products, trifluralin and chloramben, dominate the scene. The use of trifluralin increased from 1970 to 1973, while the percentage of growers that used chloramben in either state showed no distinct upward trend. The use of alachlor appears to be increasing more in Iowa than in Illinois. All other soybean herbicides were used to a much smaller extent than these three major products.

All of the soybean herbicides included in Table 26 are used preplant or pre-emergence. The use of postemergence herbicides on soybeans in Iowa and Illinois is very small, as indicated uniformly by all three surveys.

In the 1973 farmer survey conducted in this study, 92% of the Iowa soybean herbicide users and 85% of their colleagues in Illinois considered the efficacy of these products satisfactory or better in 1972 and 1973. About 5% of the respondents in both states felt that the money they spent for soybean herbicides was wasted, while 12 to 14% of them felt that they should have spent more money for soybean herbicides in the last two years. The great majority of all soybean herbicide users (about 84%) felt that the money spent for soybean herbicides was a good investment.

About 58% of the Iowa soybean herbicide users (32 of 55 respondents); and 45% of those in Illinois (98 of 217 respondents) changed products at least once since 1970. The farmers that changed soybean herbicides were asked why. 32 Iowa respondents and 81 from Illinois gave the following reasons:

	Iowa	Illinois
	% Respondents	
-- Want to increase spectrum of weed control	58	74
-- Want to experiment	18	4
-- Change to broadcast application	12	9
-- Weather	9	1
-- Crop damage	3	3
-- Changed application equipment	0	5

Cost was not mentioned as a reason for changing soybean herbicides by any grower in Iowa, and only by a single respondent in Illinois. By contrast, 2.3% of the corn herbicide users in Iowa who changed products, and 5% of their Illinois colleagues indicated cost as the reason for doing so.

Approximately two-thirds of the users of soybean herbicides in both states indicated that their costs ($ per acre) for them had gone up during the last five years, while 9% of the Iowa respondents and 4% of the Illinois respondents reported a decrease. The remaining persons in the group, close to 30% in each state, reported no significant changes in the cost of soybean herbicides during the last 5 years. Increases in the cost of soybean herbicides ranged from 5 - 100% in Iowa, from 4 - 300% in Illinois, averaging 38% in Iowa, 33% in Illinois.

A very high percentage of the soybean herbicide users in both states (96% = 53 of 55 in Iowa; 86% = 171 of 200 in Illinois) feel that all of their soybean acres need a herbicide treatment each year. The few Iowa soybean growers who did not think so stated that they treat all of their soybean acres with herbicides regardless, whereas about two-thirds of the Illinois growers (18 of 29) who felt that not all of their soybean acres need herbicides each year stated that they treat only the weedy areas.

Most of the soybean herbicide users (92% = 43 of 47 in Iowa; 96% = 179 of 186 in Illinois) feel that the soybean herbicides available today give better weed control than those available in the mid-1960's. 72% (39 of 54) of the Iowa soybean herbicide users and 67% (130 of 193) of those in Illinois stated that they would not change their use of these products if their costs would double. 24% (13 of 54) of the Iowa respondents and 21% (40 of 194) of the Illinois respondents indicated that they would quit growing soybeans if no chemical herbicides were available. Instead of soybeans, they would grow corn, small grains, alfalfa and/or forage crops.

Among the three major types of pesticides studied in this project, Iowa and Illinois growers consider soybean herbicides most essential, as indicated by the fact that over 20% of them said they would not grow soybeans without herbicides. By comparison, only 3% of the corn growers said they would not grow corn without chemical herbicides, and only 2 - 4% of the corn growers would not want to grow corn without insecticides.

D. Side Effects from the Use of Herbicides on Soybeans

The total soybean acreage in Iowa and Illinois is about 2/3 the size of the total corn acreage in the two states (Table 3). During the 1960's, a smaller percentage of the soybean acreage was treated with herbicides as compared to corn. However, during the last few years, the use of herbicides on soybeans has increased at a steep rate, to the point where today, close to 90% of all soybean acres in both states are treated with herbicides.

Two chemicals, trifluralin and chloramben, account for 70 to 80% of the total soybean herbicide use during the last few years in terms of number of acres treated. Chloramben appears to be degraded in the soil within a few months after application (Pimentel, 1971). Trifluralin is rapidly inactivated if exposed to atmospheric conditions on the soil surface. Directions for use call for soil incorporation within eight hours of application, preferably immediately. In the soil, trifluralin is moderately persistent; 80 - 90% of an applied rate will normally degrade during the growing season. However, there have been some reports of injury to corn or small grains following in the rotation after soybeans treated with trifluralin.

In the nationwide survey of weed scientists conducted in 1968 by the USDA, Illinois answered "Yes" to the question whether there was a persistence problem with soybean herbicides; 1% of treated acres were reported affected. Iowa reported no soybean herbicide persistence problem in the same survey (U. S. Dept. of Agriculture, 1972b).

In the National Soils Monitoring Program for Pesticides, 1,729 samples of cropland soil from 43 states were analyzed for residues of trifluralin. Nationwide, trifluralin residues were found in 60 samples (3.5%). Residues detected ranged from 0.01 - 0.25 ppm, the mean residue level was below 0.01 ppm. State by state, trifluralin residues were found in 2 samples out of 142 (1.4%) from Illinois, and in 5 of 151 samples (3.3%) from Iowa. Residues found ranged from 0.05 - 0.16 ppm in Illinois, and from 0.02 to 0.08 ppm in Iowa. The mean trifluralin residue level found was less than 0.01 ppm in both states.

In a follow-on study by Carey et al. (1973), trifluralin residues were found in 5 samples out of 69 (7.2%) from Illinois, ranging from 0.01 - 0.08 ppm; and in 3 out of 76 samples (3.9%) from Iowa, ranging from 0.02 - 0.06 ppm. The average residue level for both states was less than 0.01 ppm.

Chloramben was not included in these studies.

Comparing these results to those reported above for atrazine, it appears that trifluralin residues in Iowa and Illinois soils are not nearly as widespread as those of atrazine.

Trifluralin is highly toxic to fish. However, to date there have been no reports of fish kills due to the use of trifluralin as a soybean herbicide in accordance with label directions.

There are no reports on the development of resistance of soybean weeds to herbicides. However, both of the most frequently used soybean herbicides, trifluralin and chloramben, control grass weeds better than broadleaves. Consequently, weed populations in soybeans are shifting towards higher percentages of more-difficult-to-control broadleaf weeds such as cocklebur, velvetleaf, jimsonweed, and morningglory.

E. Alternatives to Chemical Control of Soybean Weeds

In our survey of Iowa and Illinois soybean growers in 1973, 24% (13 of 54) of the Iowa respondents and 21% (40 of 194) of the Illinois respondents indicated that they would quit growing soybeans if no chemical herbicides were available. (By comparison, only about 3% of the corn growers in both states indicated that they would not grow corn without chemical herbicides.)

The growers who indicated they would continue to raise soybeans if no herbicides were available answered the question how they would control weeds as follows (41 respondents from Iowa, 153 from Illinois):

	Iowa	Illinois
	% of Respondents	
-- Till and/or cultivate more	78	79
-- Hoe and pull weeds by hand	29	37
-- Rotate crops	22	9
-- Plant later	15	20
-- Grow fewer acres of soybeans	20	7
-- Increase seed rate, go to narrower rows or solid planting	2	2

Other alternatives mentioned less frequently include "plant only clean fields to soybeans"; "don't know"; and "cry a lot".

Soybean growers were also asked if they would change their soybean herbicide use practices if the cost of soybean herbicides were tiwce as high as what they last paid. Those respondents (28% = 15 of 54 in Iowa, 33% = 63 of 193 in Illinois) who said yes were asked what they would do. This question was intended to find out what possibilities growers visualize for reducing their use of herbicides on soybeans. Replies from 15 Iowa and 62 Illinois respondents were as follows:

	Iowa	Illinois
	% of Respondents	
-- Reduce soybean acres	47	5
-- Till and cultivate more	33	34
-- Reduce herbicide application rate	27	18
-- Rotate crops	13	2
-- Use different herbicides	7	15
-- Hand labor	7	13
-- Band herbicide rather than broadcast	7	3
-- Treat fewer acres with herbicide	0	19

Small percentages of the respondents mentioned changing soybean planting dates, or being unsure what to do.

University weed scientists and extension specialists do not have alternatives to the use of chemical herbicides on soybeans over and above those perceived by Iowa and Illinois soybean growers themselves, and practiced by many of them. Scientists working in this field as well as growers agree that growing soybeans in the midwest without herbicides would be considerably less profitable, and that there are currently no economically attractive alternatives to the use of soybean herbicides. Furthermore, fields in soybeans are generally more susceptible to soil erosion than under most other crops. Additional soil movements that would be caused by more tilling and cultivating would further increase the already high rate of soil loss from soybean fields.

F. Summary

Major soybean weeds in Iowa and Illinois include foxtails, cocklebur, velvetleaf, smartweed, and wild sunflower (largely the same species as those found in corn). Several field studies indicate that weeds cause substantial soybean yield losses in spite of the availability and use of soybean herbicides. In a six-year study, the use of herbicides on soybeans was more profitable than three timely cultivations. Herbicide use was unprofitable only in one out of the six years studied.

Of the Iowa and Illinois soybean growers surveyed in this project, 98% used herbicides on soybeans in 1973. An estimated 80 to 85% of the total soybean acreage in the two states is currently treated with chemical herbicides. Almost all of the larger soybean growers use herbicides and treat close to 90% of their soybean acreage. The two most frequently used soybean herbicides were trifluralin and chloramben.

Among the three major types of pesticides studied in this project, Iowa and Illinois growers consider soybean herbicides most essential. A high percentage of the soybean herbicide users (96% in Iowa; 85% in Illinois) feel that all of their soybean acres need a herbicide treatment each year. Over 20% of the soybean growers stated that they would quit growing soybeans if no herbicide were available. (By comparison, only 3% of the corn growers said they would not grow corn without herbicides, and only 3-6% would not grow corn without insecticides.)

Environmental monitoring data currently available are not adequate to evaluate whether or not a soybean herbicide soil persistence problem exists. In a nationwide survey of weed scientists in 1968, Illinois stated that there was a persistence problem with soybean herbicides in the state, 1% of treated acres were reported affected. In the same survey, Iowa did not report a soybean herbicide persistence problem.

There are no reports on the development of resistance of soybean weeds to herbicides. However, both of the most frequently used soybean herbicides, trifluralin and chloramben, are more effective against grass than against broadleaf weeds. As a result, soybean weed populations are shifting towards greater preponderance of more-difficult-to-control broadleaf weeds such as cocklebur, velvetleaf, jimsonweed, and morningglory.

Among alternatives to the use of soybean herbicides, increased tillage and cultivation, hand-hoeing and -pulling of weeds, and crop rotation were mentioned most frequently by the soybean growers interviewed. Weed scientists and extension specialists do not propose additional alternatives to the use of chemical herbicides on soybeans. Weed scientists, extension specialists and growers agree that the production of soybeans in the midwest without herbicides would be considerably less profitable and more difficult, and that there are currently no economically attractive alternatives to the use of soybean herbicides.

IX. FARMERS' SOURCES OF INFORMATION ON PESTICIDES

The data presented in Chapters IV - VIII of this report amply document that chemical herbicides and insecticides are used in large quantities on a high percentage of all corn and soybean acres in Iowa and Illinois. The Illinois Cooperative Crop Reporting Service (1973b) reports that in 1972, 77% of the corn acres and 86% of the soybean acres treated with herbicides were treated by the farmers themselves, the balance by custom applicators. About 94% of the corn acres, and 71% of the soybean acres that received insecticide treatments in 1972 were treated by farmers. Thus, more than three-fourths of the pesticides used on these crops are applied by growers.

There are more than 250,000 individual farmers in Iowa and Illinois. The foregoing data indicate that most of them handle and apply pesticides. Therefore, it is important to know how farmers obtain information on pesticides, where this information originates, and how it travels from the source to the receiver. A major effort in this study was focused on these questions.

A. Previous Studies

Smith and Heady (1970) studied the characteristics of commercial farm operators and their employees in Iowa. They interviewed 114 farm operators on 98 farms. This group had an average education of 11.8 years (range 6 - 19 years), just less than a high-school education. Of the 114 operators interviewed, 65 (57%) had completed highschool; 24 others (21%) had at least some college education, but only 17 of the latter had studied agriculture. The study further showed that of all 114 commercial farm operators interviewed, -

-- 70 (61%) had no formal agricultural education;
-- 20 (18%) had highschool vocational agriculture training only;
-- 10 (9%) had college agriculture training only;
-- 4 (4%) had both vocational and college agriculture training;
-- 6 (5%) had veterans' training in agriculture;
-- 3 (3%) had both veteran's training and college agriculture.

A considerable number of authors have dealt with the process of adoption of new ideas, new technologies and new farming practices by farmers, including Beal and Bohlen (1957), Fliegel (1956), Fliegel and Kivlin (1962, 1966), and Kivlin and Fliegel (1968). However, none of these deal specifically with crop protection practices and pesticides.

Farm magazines including Wallaces Farmer and Prairie Farmer survey farmers from time to time regarding their sources of information on a variety of subjects, sometimes including crop protection. However, these surveys usually do not cover all of the channels through which farmers may receive information, but are limited to certain types of channels such as, for instance, comparisons between farm magazines, daily newspapers, radio, and TV. The results of such studies are useful to actual and potential advertisers.

Prior studies that were more directly applicable to the objectives of this project include those by Beal et al. (1966), Beal et al. (1969), Kerr (1970), and Hestand et al. (1971).

In 1965, Beal et al. (1966) conducted personal interviews of 229 Iowa farmers who farmed at least 70 acres in 1964 and personally made the major management decisions for their farming operations. One section of the survey dealt with what farmers know about pesticides.

Respondents' knowledge of soil, crop and livestock insecticides was tested by 16 statements with which the interviewee had to agree or disagree. Correct answers ranged from 10 - 83%, averaging 43%. An average of 18% incorrect answers were given, the balance (39%) were "don't know" or no-opinion answers.

A similar set of 14 agree/disagree statements dealt with farmers' knowledge of herbicides ("weed, grass and brush killers"). In this case, an average of 47% (range 10 - 73%) of correct answers were given. Incorrect answers averaged 23%, no-opinion answers 29%.

A set of questions on proper safety precautions and on general knowledge about pesticides and their use scored somewhat better, with correct answers averaging 71 - 85%.

When the responses to all 44 knowledge statements on pesticides from all 229 participants in the survey were pooled, the average number of correct responses was 24 out of 44, that is 55%.

Another section of the study by Beal et al. (1966) dealt with the information sources used by Iowa farmers. Respondents were asked to indicate which of 29 specified sources of information on pesticides they were presently using. Responses were as follows:

	% of Respondents
-- Farm magazines and farm papers	94.3
-- Pesticide label	90.4
-- Other farmers in the community	67.7
-- Local agricultural chemical dealers	60.7
-- Radio	48.9
-- County extension personnel	47.6
-- Veterinarian [1/]	43.7
-- Television	42.4
-- Agricultural chemical company publications	41.5
-- Newspapers	35.8
-- Agricultural extension publications	34.9
-- Meetings sponsored by local agricultural chemical dealers	25.3

(Continued on next page)

(Continued)	% of Respondents
-- Family members	25.3
-- Meetings sponsored by ag. chemical companies	24.9
-- U. S. Dept. of Agriculture publications	20.5
-- Agricultural chemical manufactuers' or wholesalers' salesmen	17.9
-- Meetings sponsored by the State University and Extension Service	16.6
-- Vocational agriculture teacher	14.4
-- State University specialists	14.0
-- Iowa Farm Science publication	10.0

1/ Livestock insecticides were included in the survey

The remaining information sources (Farm Bureau; landlord; community organization; banker; other publications; farm manager; Iowa Institute of Agricultural Medicine; A.S.C. meetings; and past experiences) were mentioned by less than 10% of the respondents.

Additional questions were asked to determine the most useful source of information in regard to specific aspects of the use of pesticides. The pesticide trade, especially local dealers, and farm magazines and farm papers were rated most useful regarding which chemical to use for a particular purpose. Pesticide labels were rated most useful regarding methods and rates of application, handling and safety precautions, and hazards and possible harmful consequences of misuse.

Respondents in this survey also indicated from whom they purchased pesticides. Pesticide suppliers were as follows:

	% of Respondents
-- Feed and seed store	62.0
-- Farmers co-op elevator	60.7
-- Veterinarian[1/]	52.8
-- General farm supply store	27.9
-- Drugstores	24.0
-- Farm service companies	22.3

1/ Livestock products were included in the survey

All remaining sources of supply were mentioned by less than 20% of the respondents.

Finally, farmers participating in this survey were asked to express their opinions on pesticide dealers' qualifications as sources of information on pesticides. 55% of the respondents considered their dealers to be a "qualified source of information on some aspects of agricultural chemicals and their use", while 27% rated them a "highly qualified source of information on all aspects of agricultural chemicals and their use". Of the remaining respondents, 9% considered dealers not qualified, 7% considered them to be poorly qualified, and 2% did not answer the question.

In a related question, 13% of the respondents expected their pesticide suppliers to provide information only; 75% expected them to provide information and make recommendations; 9% considered dealers not qualified to give information, while 4% did not reply to the question.

Thomas and Evans (1963) summarized the results of four different studies on farmers' information sources that were carried out by members of the Extension Editorial Office of the University of Illinois, College of Agriculture, Urbana. Most of these surveys dealt with problems other than pesticides, but one of them included an item pertinent to our inquiry.

In a study by Jones in 1959 in which 100 farmers in southern Illinois were personally interviewed, replies to the question "What one source would you probably look to for information on how to control weeds with chemicals?" were as follows: Seed and fertilizer dealer - 30%; county farm adviser - 24%; neighbors - 5%; local banker, past experience, university specialist - 1% each. 2% of the respondents gave unspecified miscelleanous answers, the balance (36%) said they did not know.

Kerr (1970) interviewed 44 farmers in Winnebago and Boone Counties in northern Illinois in regard to their herbicide use practices. Included in the scope of this study were characteristics of the operators interviewed and of their farms; weed problems; application problems encountered in the use of herbicides such as clogging of nozzles and strainers, water hauling, irritation (operator? skin? mucuous membranes?), separation or settling of the spray mixture, foaming, pump breakdown, calibration, spray drift, mixing difficulties, and safety precautions. Regarding use of the information on herbicide labels, 22 respondents (50%) reported that they read the product label before purchase; 12 (27%) read it at the time of purchase; 32 (73%) read it before use of the product; 35 (80%) read it at the time of use, and 4 (9%) reported reading it after application had started.

Several questions in this survey pertain to the importance of price in the selection and use of herbicides. In choosing between two herbicides of nearly equal performance, 61% of the respondents would rate previous good experience with a product more important than price; 52% of the respondents would prefer familiarity with the product over price, while 27% would buy the lower-priced material. Good crop tolerance and weed control were rated more important than a lower price.

By way of general comments, some criticism was voiced of farm magazines because of the relationship of their reporting to advertising. Respondents expressed the view that farm magazines' reporting on herbicide performance was too general to be useful. Respondents also said that the pesticide industry should reduce prices if possible; improve products by increasing safety and effectiveness; be honest and complete in informing the user; do a better job of grading and packaging; and move from a profit motive to a service motive.

Hestand et al. (1971), conducted a similar survey in Wabash and Edwards Counties in southeastern Illinois, using a slightly modified version of the survey form developed by Kerr (1970), and following the same objectives. 43 farmers were interviewed in this study. The results obtained were generally quite similar to those reported by Kerr, except for variations in weed problems and other factors due to the differences in geographic location between the two survey areas. Regarding use of herbicide labels, 34 (79%) respondents in this survey reported that they looked at it before or at the time of purchase; 35 (81%) read it after purchase and before use; 20 (47%) read it at the time of use; and 2 (5%) after start of application.

B. This Study

Beal et al. (1966) have pointed out that the communication process contains four basic elements, i.e., the sender, the channel, the message, and the receiver. The following discussion will be structured accordingly, except for a somewhat different order because the prime interest of this study centers on the receiver, that is the farmer.

1. Receivers' Use and Perception of Pesticide Information Sources

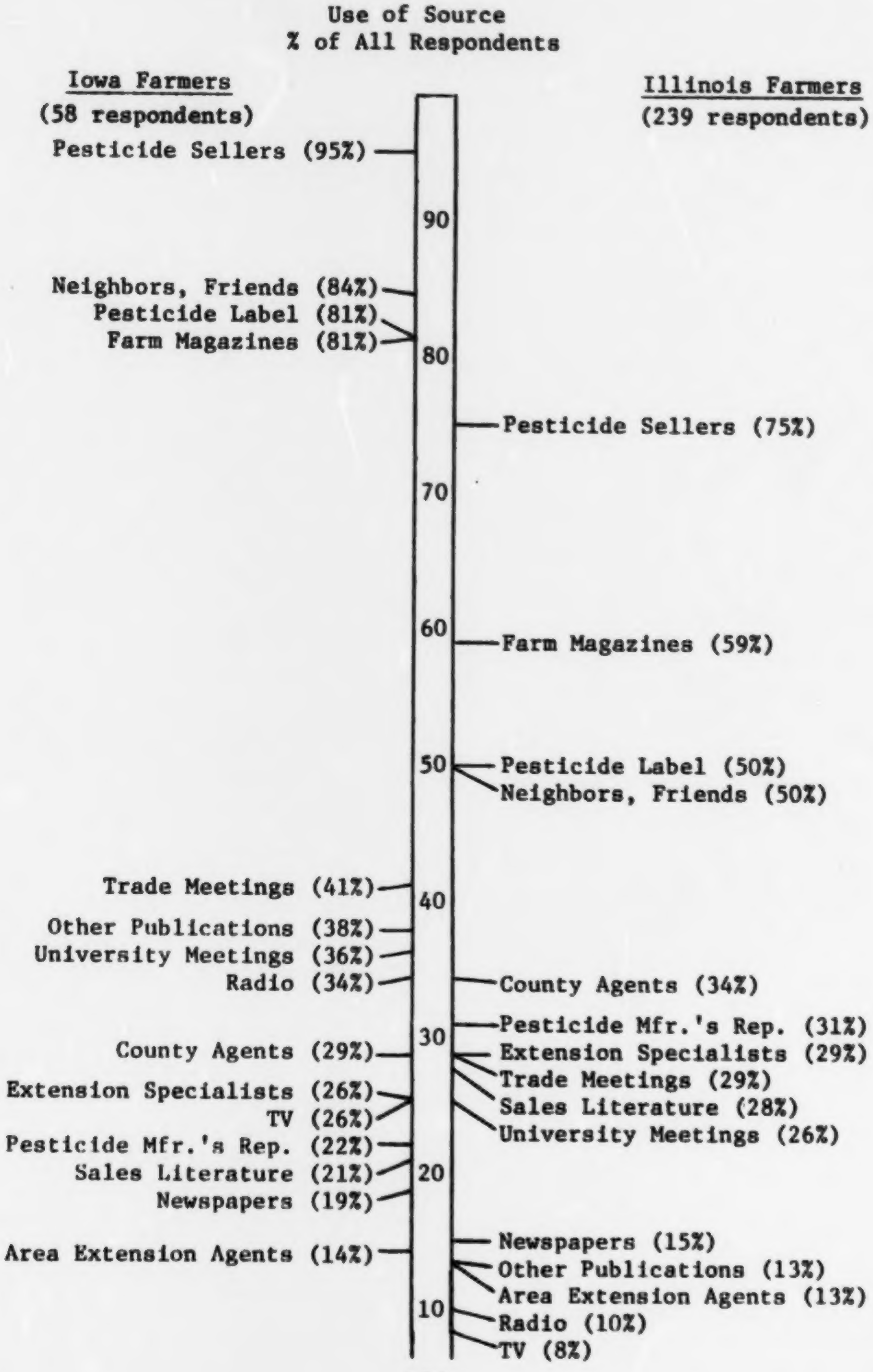
In the survey of Iowa and Illinois farmers conducted in this project, respondents were asked which of 15 specified sources of information they used in 1972 and 1973 in deciding if, when, and how to use pesticides, which product to use, and what rate of application. All respondents (58 in Iowa, 239 in Illinois) answered this set of questions very thoroughly. Figure 3 summarizes the results regarding the extent of use of these sources by the Iowa and Illinois respondents. In evaluating these results, it must be remembered that, as outlined in the Methods section, Iowa farmers were interviewed in person, Illinois farmers by mail.

Only 4 of the 15 information sources were used by more than 50% of the respondents in both states, i.e., (in decreasing order of extent of use) pesticide sellers; farm magazines; neighbors, friends and relatives; and pesticide labels. 30 to 50% of the Iowa interviewees obtained information on pesticides from trade meetings; publications other than farm magazines, newspapers or sales pamphlets; state university meetings or field demonstrations; and the radio. 30 to 50% of the Illinois respondents received pesticide information from county agents (farm advisers) and pesticide manufacturers' representatives. All other sources of information were used by less than 30% of the respondents in both states.

In the next step, respondents' perception of the usefulness of the pesticide information received from these sources was examined. For each source that a respondent reported he used, he was asked to indicate whether the information received was "very good", "satisfactory", or "unsatisfactory". Usefulness ratings were computed from these entries by averaging for each source the "very good" ratings, then subtracting the averaged "unsatisfactory" ratings.

The following four information sources were considered most useful by the respondents and scored usefulness ratings higher than 50 (rating following each source): pesticide labels (59); pesticide sellers (56); neighbors, friends, relatives (53); and university extension specialists (52). The following four information sources were considered least useful: television (minus 8);

Figure 3 : Sources of Information on Pesticides and Extent of their Use by Iowa and Illinois Farmers, 1973



newspapers (6); radio (10); and sales leaflets (10.5). All of the remaining information sources scored usefulness ratings between 10 and 50.

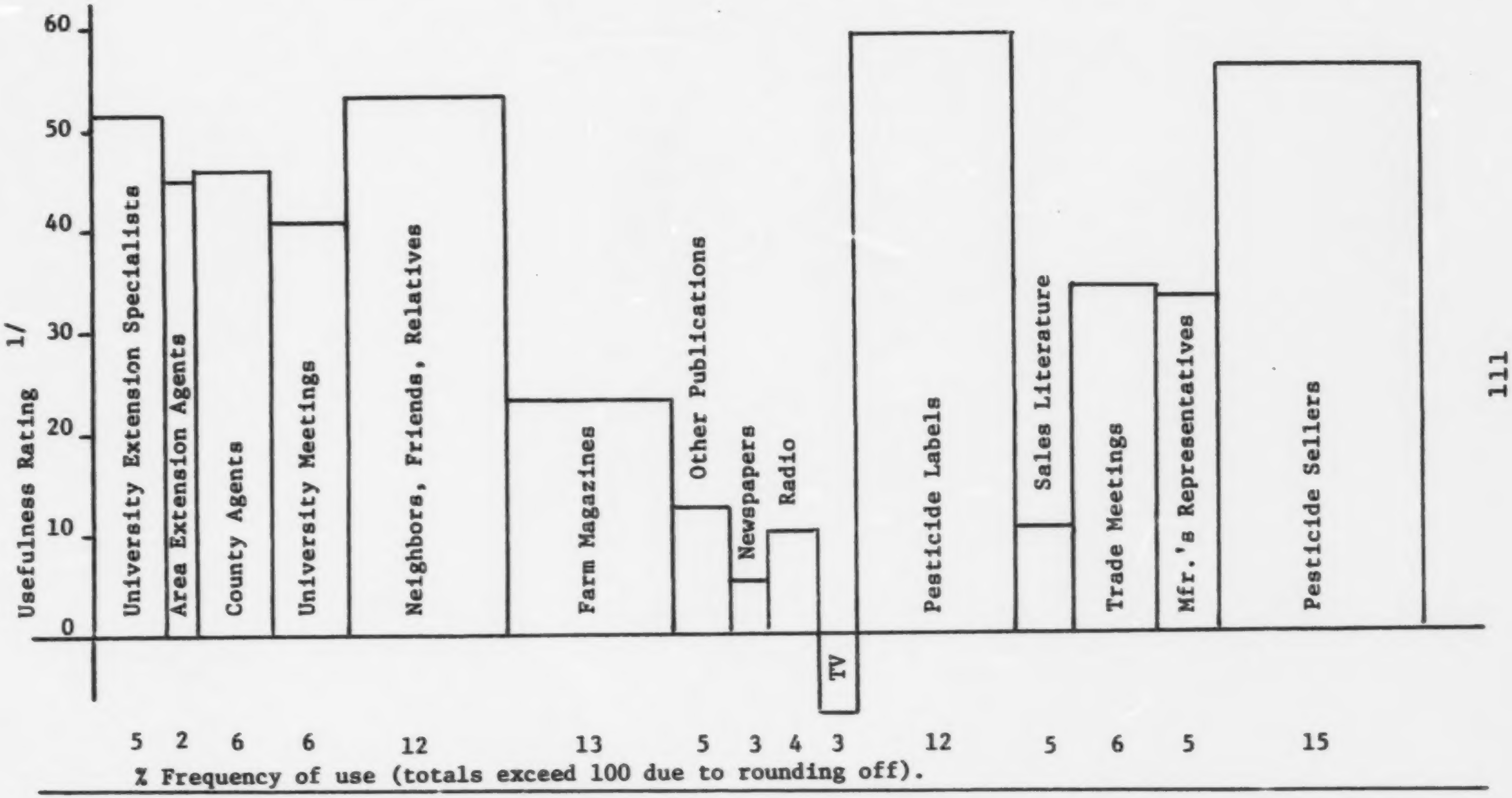
Figure 4 summarizes the extent of use of the pesticide information sources and their usefulness as perceived by the participants in our survey. For each information source, frequency of use (percentage share of all pesticide information impressions) is plotted against the usefulness rating. The width x height = area of each bar is thus an indication of the relative importance of each source in farmers' pesticide use decisions.

Pesticide labels, pesticide sellers, and neighbors, friends and relatives ranked high in usefulness as well as in frequency of use. University extension specialists, area extension agents, county agents (farm advisers), and university meetings also ranked high in usefulness, but much lower in frequency of use. Among these four sources of pesticide information supported by public funds, university extension agents, county agents and university meetings scored usefulness ratings between 40 and 50. Pesticide information received at meetings or field demonstrations by pesticide producers or sellers ("trade meetings") or from representatives of pesticide manufacturers rated 34 and 33.5 on the usefulness scale, respectively.

Farm magazines are read by a high percentage of Iowa and Illinois farmers. They accounted for 13% of all pesticide information impressions, but scored relatively low (23) in regard to their usefulness as pesticide information sources. This is not surprising because such magazines generally do not attempt to convey specific, detailed pesticide use information to growers.

As mentioned earlier, some of the respondents in the study by Kerr (1970) expressed criticism of farm magazines, suggesting a relationship of their reporting on pesticides to their advertising revenue. In the report by Hestand et al. 1971), "suggestions for

Figure 4: Sources of Information on Pesticides by Extent of Use and Usefulness as Perceived by Iowa and Illinois Farmers, 1973



1/ %"Very good" ratings less % "Unsatisfactory" ratings. (TV received 5.5% "Very good", 13.5% "Unsatisfactory" ratings, resulting in a negative rating of 8.)

farm magazines" read in part as follows: "Do features on proven methods, require proof in advertising, cut the 'bologna'".

Other media including newspapers, radio, television, sales literature, and other publications scored low on the usefulness scale and were not used extensively by the respondents as sources of information on pesticides.

Comparing these findings to those of Beal et al. (1966), it is noteworthy that the same four sources of information on pesticides were used most frequently by the respondents in both surveys, i.e., pesticide labels; pesticide sellers; farm magazines; and neighbors, friends and relatives. In both studies, these were the only four information sources that were used by more than 50% of the respondents. Comparing extent of use of the remaining sources between the two surveys, it appears that university extension specialists and meetings and field demonstrations conducted by the university reached farmers more frequently in 1973 than in 1965. Conversely, newspapers, radio, sales literature and county agents were mentioned less frequently as pesticide information sources by farmers in 1973 than in 1965.

To determine how well farmers use the pesticide information they receive through these various sources, an analysis was made of all responses to our 1973 farmer survey that might indicate pesticide misuses.

In the survey, 217 Illinois corn growers made a total of 460 product entries in response to the question which corn herbicides they used in 1973 or 1972. Five times, products were mentioned (1.1% of all responses) that are either not herbicides, or herbicides that are not registered for use on corn and would, most likely, damage corn, i.e. (numbers in parentheses = times mentioned), carbaryl, an insecticide (1); and the herbicides metribuzin (1), dinitramine (1) and trifluralin (3).

In response to the question which soybean herbicides they used in 1973 or 1972, 213 Illinois soybean growers made 371 product entries. Products that are not registered for use on soybeans were mentioned 5 times (1.3% of all responses); they were atrazine (1), paraquat (1), and propachlor (3).

Replying to the question which insecticides they used in 1973 or 1972 for the control of corn insects, 157 Illinois farmers made 194 product entries. Products that are either not insecticides, or that are not registered for use on corn were mentioned 8 times (4.1%). These included the herbicides atrazine, butylate, 2,4-D, linuron, and propachlor; the fungicide captan; and the nonregistered products Counter and ID 2570.

In the surveys of Iowa farmers by Wallaces Farmer (1970, 1972), there were comparable percentages of wrong products mentioned. Soybean growers reported using as soybean herbicides atrazine (0.5% in 1970; 1.0% in 1972); 2,4-D (1.5% in 1970; 0.3% in 1972); and propachlor (registered for use on soybeans for seed only; 1.0% in 1970; 1.8% in 1972).

In the 1972 survey of Illinois farmers by Prairie Farmer (1972), soybean growers reported using as soybean herbicides atrazine (0.2%) and propachlor (0.4%).

If these percentages of reported misuses would be indicative of actual misuses of pesticides in the field, there would be reason for concern. It is possible, of course, that at least some of them were cases of misreporting rather than actual misuse. However, extension personnel as well as pesticide sellers report that a certain amount of misuse of pesticides does occur. This is not surprising, considering the findings by Smith and Heady (1970) regarding the educational level of commercial farm operators, those of Beal et al. (1966) on their knowledge of pesticides, those of Kerr (1970) and Hestand et al. (1971) on the reading of pesticide labels, and the fact that about 200,000 individual farmers apply pesticides in Iowa and Illinois alone (see pp. 84-86 and 89-90).

2. Senders of Pesticide Information

There are two major originating sources (or senders) of information on pesticides, i.e., the basic manufacturer, and federal and state agencies. The basic manufacturer of a pesticide usually accumulates all chemical, physical, analytical, toxicological, physiological, efficacy, safety and other data required for registration of the product. The research and development work necessary to obtain these data is often carried out in part in the commercial company's own facilities, in part through contracts or other arrangements on the outside.

Many federal and state crop protection scientists work on pesticides, especially in situations where certain products will be useful to agriculture in a given area, where regional or local directions for use may have to be developed, and/or where there may be concern about residues or undesirable side effects.

Information from both of these basic sources, pesticide manufacturers and public agencies, is used in the writing of pesticide labels. Such labels are then registered by the U. S. Environmental Protection Agency. In addition, state registrations are required in many states.

3. Public Agency Channels

Federal and state crop protection scientists and extension workers convey the results of their work on pesticides primarily through publications, including papers in the scientific literature; popular articles, bulletins and leaflets; weed, insect, and disease control recommendations and newsletters; and meetings and field demonstrations.

The results of the farmer surveys discussed earlier in this chapter, especially the 1973 survey conducted in this project, indicate that state university extension specialists, area extension agents, county agents and university meetings and demonstrations were not among the most frequently used sources of information on pesticides. All four of these sources combined accounted for only 19% of the total pesticide information impressions (Figure 4). We therefore examined to what extent extension publications, especially weed, insect and disease control recommendations and newsletters, might extend the outreach of federal/state crop protection research and extension specialists.

One example selected were the Illinois pest control recommendations. Weed control recommendations (but not the insect or disease control recommendations) are included in the "Illinois Agronomy Handbook", a publication by the University of Illinois' Department of Agronomy that is issued annually. About 13,000 copies of this handbook were printed in 1973. Additional copies of the weed control recommendations (as well as copies of the insect and plant disease control recommendations) are included in the Illinois Custom Spray Operators' Training School Manual of which about 1,300 copies are printed annually. An additional 3 - 4,000 copies of these recommendations are distributed at various meetings and "clinics" throughout the state, and about 1,000 copies are sent out in response to mail requests. Thus, it appears that about 19,000 copies of the Illinois weed control recommendations are distributed each year. Of the approximately 6,000 copies distributed via the custom spray operators' training school manual and as single copies, we estimate that less than 1,000 reach growers directly, based on the percentage of growers attending the meetings at which these manuals and single copies are made available. If 11,000 copies of the Agronomy Handbook would reach growers directly, about 12,000

Illinois farmers would receive the State weed control recommendations, that is approximately 10% of all farmers in the state. The insect and plant disease control recommendations probably reach a much smaller number of growers directly because they are not included in the Agronomy Handbook which appears to be the prime vehicle by which weed control recommendation reach the growers.

The Federal/State Cooperative Extension Service at Iowa State University publishes an "Insect, weed and plant disease newsletter" at weekly intervals throughout the crop growing season, for a total of about 20 issues per year. The Illinois Cooperative Extension Service has a very similar publication, called "Insect, weed and plant disease survey bulletin", that had 24 issues in 1973.

Both of these publications are very similar in format and content. They convey timely information on weed, insect and disease problems and methods on how to cope with them week by week throughout the growing season, along with notes on regulatory and similar actions that may be of importance to growers. Table 27 gives a breakdown of the distribution of both publications. The distribution pattern in both states is quite similar; only about 2% of the copies in Iowa, and 10% of the Illinois copies go to farmers directly. By far the greatest percentage of the newsletters in both states go to the pesticide trade, the next largest share to state university and cooperative extension service personnel within the state and, in the case of Iowa, to surrounding states.

The number of personnel involved in generating and transmitting pesticide information was also examined, using the situation in Iowa as an example. At Iowa State University, there are 7 extension specialists dealing full-time with crop protection problems, i.e., 3 in entomology and 2 each in weed science and plant pathology. There are 12 area extension agents and 100 county agents, the latter also sometimes referred to as "farm advisers". Area extension

Table 27: Distribution of the Weekly Iowa and Illinois Insect, Weed and Plant Disease Newsletter/Survey Bulletin, 1973

Recipients	Distribution Number of Copies per Issue	
	Iowa	Illinois
State University and Cooperative Extension Service Personnel	215 (18%)	199 (20%)
Surrounding States' Extension Personnel	100 (9%)	1/
Pesticide Producers, Sellers, Fieldmen, Commercial Applicators	600 (51%)	695 (70%)
Newsmedia (Newspapers, Radio and TV Stations)	1/	
Vocational Ag. and Area Schools	225 (19%)	1/
State and District Foresters	15 (1%)	1/
Farmers	20 (2%)	99 (10%)
Totals	1,175 (100%)	993 (100%)

1/ Not mentioned

Sources: Stockdale, 1973; Luckmann, 1973.

agents and county agents, however, have to cover all crop, livestock and horticultural problems of their farm and/or urban clientele and thus deal with crop protection and pesticide problems only part-time.

4. Pesticide Trade Channels

One of the prime channels transmitting pesticide information from pesticide producers to farmers is the pesticide label. In addition, pesticide producers convey information on their products through sales pamphlets and other literature, advertisements, and through personal contacts between their representatives and all other parties involved in distributing pesticides and pesticide information, especially pesticide wholesalers and retailers.

To obtain information on the number of personnel involved in transmitting pesticide information through pesticide trade channels, we contacted the Iowa State Department of Agriculture to determine the number of pesticide retail outlets in the state. That information is not available as such. However, the Department advised that fertilizer outlets have to be licensed in the State of Iowa, and that there are 1,274 such outlets licensed at present. It is estimated that most of these (more than 90%) also sell pesticides. In addition, pesticides are also sold by commercial pesticide applicators. Including urban operators, there are about 1,500 licensed pesticide applicators in the state. The great majority of these are farm pesticide applicators.

We were further advised that there are currently about 4,750 individual pesticide products registered in the State of Iowa by about 600 individual registrants (more than 95% of these products on Federal, rather than intrastate labels).

The State of Illinois Department of Agriculture was also contacted for information on the number of sales outlets for agricultural pesticides in Illinois; the number of salesmen selling such products in Illinois; and the number of agricultural pesticides registered in Illinois intrastate and/or on national labels. Illinois advised that they currently have 4,895 pesticides registered, but that breakdowns by national versus intrastate labels, or by agricultural versus nonagricultural pesticides are not available. In response to the first two questions, we were informed that the state does not have any information or estimates on the number of salesmen or sales outlets selling agricultural pesticides in Illinois.

Trade sources finally proved more fruitful in rounding out the picture. Combining information received from the Iowa State Department of Agriculture and from several trade sources, the following estimate on the number of personnel involved in promoting and selling pesticides and distributing information on pesticides in the state of Iowa resulted:

-- At least 28 basic pesticide producers develop, advertise and sell their products in Iowa.

-- These firms employ about 130 field representatives who engage full-time in the development, demonstration, promotion and selling of pesticides.

-- Additional field representatives are employed by the larger wholesalers.

-- There are approximately 1,800 retail outlets for agricultural pesticides in the state, including 5 - 600 custom applicators.

-- There are over 4,000 persons involved in retail selling of agricultural pesticides in Iowa. The great majority of the persons in this group also handle other agricultural supplies and therefore deal with pesticides and pesticide information only part-time.

The last two of these estimates were obtained as follows. In a survey of Iowa agricultural chemical dealers by Beal et al. (1969), it was found that the number of employees (including the manager) of 126 dealers interviewed ranged from 1 to 27. The majority of the businesses had between 1 and 5 employees, in addition to the manager. We estimate (conservatively) that there are about 1,250 agricultural pesticide retailers with an average staff of three persons each, including the manager. We further estimate that there are at least 550 commercial applicators who dispense pesticides and information. The total number of personnel involved in retail selling of agricultural pesticides would thus be 4,300, hence our estimate of "over 4,000".

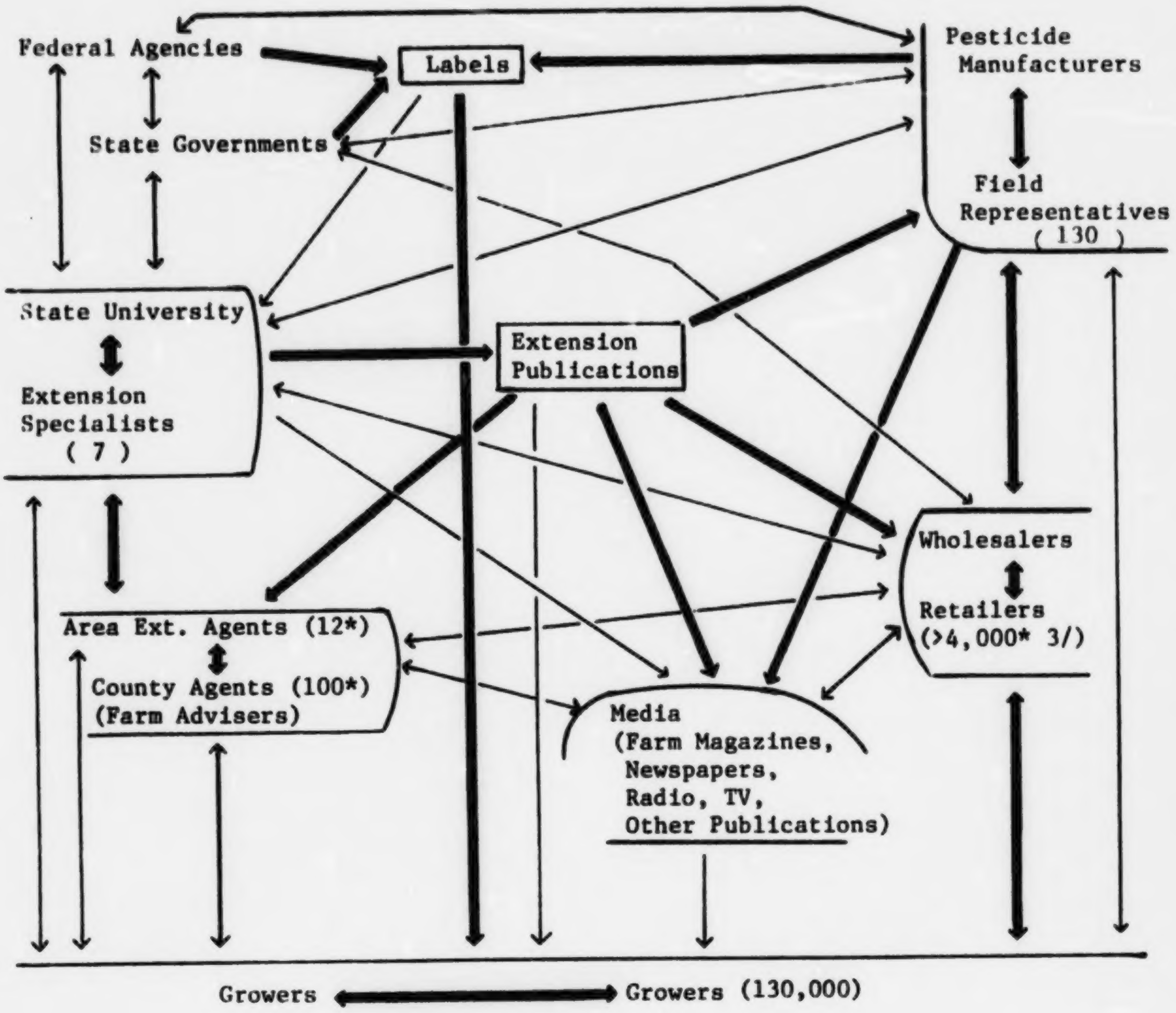
5. Flow Patterns of Pesticide Information

Figure 5 shows the flow patterns of pesticide information from the originating sources to growers, based on all data and surveys discussed in the preceding sections of this chapter. For the key information conveyors, the approximate numbers of workers involved in transmitting pesticide information in the State of Iowa have been included.

The important findings are as follows:

- Pesticide labels and pesticide retailers are the two prime channels that convey pesticide information to growers.
- Pesticide information from extension specialists, area agents and county agents reaches only a small percentage of growers directly.
- Extension publications (pesticide use recommendations, newsletters, etc.) reach only a small percentage of growers directly; they are used primarily by the pesticide trade.
- Extension publications sent to media (farm magazines, newspapers, radio, TV) may be reproduced or otherwise used by these media, but this does not produce a significant pyramiding effect because growers do not use these media extensively as sources of information on pesticides and do not consider them to be very useful in this regard.
- Growers communicate extensively with other growers.

Figure 5 : Sources and Routes of Information on the Use of Agricultural Pesticides in Iowa and Illinois 1/ 2/.



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* Deal with pesticide problems only part-time.

1/ Heavy lines indicate predominant routes.

2/ Numbers in parentheses indicate approximate number of workers in specified category in the State of Iowa.

3/ Assumptions: There are about 1,250 sellers of agricultural pesticides in Iowa, and an average of 3 persons per outlet selling pesticides, plus about 550 commercial applicators retailing agricultural pesticides.

The pesticide information flow patterns in Illinois are very similar to those in Iowa. Illinois also has an area extension structure between the university and the counties, and an almost identical number of counties. The basic structure of the pesticide trade is very comparable. The numbers of persons involved in sending and transmitting pesticide information at different stations in the flow pattern may vary somewhat between the two states, but the basic situation is very similar. In Illinois as well as in Iowa, pesticide specialists and extension workers in public service are outnumbered by those in the pesticide trade by wide margins.

Comparing the data in Figures 3, 4 and 5, it is interesting to note that university extension specialists, despite their small numbers, managed to reach 26% of the Iowa growers and 29% of the Illinois growers directly (Figure 3), and to produce 5% of all pesticide information impressions (Figure 4). Pesticide manufacturers' representatives, outnumbering extension specialists by a margin of almost 20 to 1, reached 22% of the Iowa growers and 31% of the Illinois growers directly, and accounted for 5% of all pesticide information impressions. This comparison speaks very well for the efficiency and effectiveness of university extension specialists.

Area extension agents and county agents likewise seem to be very efficient conveyers of pesticide information, considering their numbers. Nevertheless, even though pesticide trade representatives seem to be less efficient per caput than their public servant counterparts by these comparisons, they outnumber the latter by such wide margins that overall, they reach a much higher percentage of farmers in both states directly and produce a much higher percentage of all pesticide information impressions than the public servants.

The information flow pattern depicted in Figure 5 worked very well as long as the objectives of the pesticide trade were essentially in harmony with those of federal and state agencies, i.e., as long as pesticide development and increased use of pesticides meant progress to both groups. There are indications that problems may arise in situations where this congruity of objectives no longer exists such as, for instance, if the extension service issues messages that may reduce the use of pesticides. A case in point from within the study area is the soybean insect situation briefly discussed in Chapter V of this report. More serious problems in this regard have arisen, for instance, in the state of Arizona, according to verbal reports at a recent scientific meeting (Carl, 1974; Good, 1974).

6. Pesticide Information Messages

Farmers who have pest problems in their crops need the following information:

- What pest or pests are causing the problem?
- Should I use a pesticide?
- If not, what other choices are there?
- If so, what products are available? Which is the best, considering effectiveness, use rates, safety to crops and to operators, price, etc.?
- When and how should I use the product of choice (rate of application, equipment, timing, safety precautions, etc.)?
- How much will it cost, and how much profit will it return?
- Will there be side effects? Now? Later?

To determine to what extent the pesticide information messages reaching growers in Iowa and Illinois answer these questions, several aspects were studied.

a. Information on pesticide selection, use, costs, and profits.

All but the last one of the farmer questions listed above fall into this category and, since they are interrelated, they will be considered together.

First, the weed and insect control recommendations published annually by the Iowa and Illinois Cooperative Extension Services were examined. Neither the Iowa nor the Illinois weed or insect control recommendations include information on the cost of the products whose use is recommended or "suggested". The Iowa weed control recommendations do not include dosage rates. The recommendations do not include all products federally registered and legally available for use within the state, but they do not indicate which individual product or products may be the best for a given purpose.

Crop protection scientists in both states with whom we discussed this question stated that they do have more specific information on the advantages and disadvantages of the herbicides and insecticides included in these recommendations. They would gladly make such information available in response to direct, individual questions, but would not want to "go out on a limb" by making their written recommendations more specific. Some also opined that repercussions from the suppliers of products that might not receive top rating were a deterrent to publishing more specifics, and to grading products by their advantages and disadvantages. It was also pointed out that sometimes, comparable data pertinent to the situation in the state are not available for all products, and that conditions within the state may vary, resulting in variations in product performance from place to place.

Pressing the point further, research and extension workers were asked to assume that they had valid data and were convinced of the existence of genuine differences between pesticides. Most of them felt that even then, they would rather not publish more specifics that would differentiate between individual pesticides to a greater degree.

All entomologists and weed scientists interviewed felt quite strongly that they should not become involved with the cost and profit aspects of individual pesticides, admitting that this would leave growers without an unbiased source of advice on the economics of their pesticide choices.

It thus appears that there is a reservoir of detailed and specific information on the performance and relative usefulness of individual pesticides at the university level that is not published. (However, as pointed out in Section 5, of this chapter, even the information that is published reaches growers only to a limited extent, and most of it not directly, but through the channels of the pesticide trade.)

Next, we examined whether Iowa and Illinois farmers themselves might feel a need for more specific crop protection advice than they are currently receiving. Several questions along these lines were included in the farmer survey.

The first question in this series asked how many weed and/or insect control demonstration tests the respondent personally visited during the last three years, and whether the tests were conducted by federal, state, university or county personnel; or by pesticide companies or sellers. 48% (28 of 58) of the Iowa and 42% (99 of 238) of the Illinois respondents reported that they had visited insect and weed control field tests and/or demonstrations in person during the last three years. The number of tests visited ranged from 1 to more than 10; most respondents (79%) had seen between 1 and 3 tests. 43% of the tests visited by Iowa respondents, and 65% of those visited by Illinois respondents were put on by public agencies, the balance by the pesticide trade.

Concerning use of the results of such tests beyond the visual impressions, 57% of the Iowa farmers and 31% of the Illinois farmers received test results in written form. 21% of the Iowa and 52% of the Illinois growers stated that they had not received such written reports in the past, but would like to receive them in the future. Only about 20% of the respondents in both states felt that such data would not be of value to them.

The next question asked:

> "Assume a competent crop protection advisory service would give you precise information (by mail, telephone, radio, etc.), based on insect and weed counts, soil properties, etc., on which herbicides and insecticides to use (by product name); the amount to use per acre; and the date the product or products should be applied for best results, would you follow the advice?"

Replies from 58 Iowa and 239 Illinois respondents were as follows:

	Yes	No	Undecided
Iowa	81%	17%	2%
Illinois	69%	18%	13%

Next, growers were asked if they would refrain from using a pesticide if the advisory service would inform them that some or all of their fields did not need treatment because of low weed or insect infestations. 85% of the Iowa and 63% of the Illinois growers said they would follow the advice and not treat.

About one-half of all respondents stated that they would be willing to pay a fee for such a service, ranging from $0.05 to $5.00/acre, averaging $0.76/acre in Iowa, $0.70/acre in Illinois.

A surprisingly large number of respondents made additional, unsolicited comments on this question. A sampling follows:

> "You don't need anyone to tell you whether you need herbicides or not, you can tell by the looks of your fields. As far as insects, no one can predict very accurately what damage they will do regardless seemingly large build-ups. Weather and parasites turn things around".
>
> "Would be interested in the insecticide portion but I feel I know the weed problem as well as anyone on this farm".
>
> "Extension is good enough and it is free".
>
> "I get most of this information from my chemical dealer".
>
> "Would pay fee if soil test was also included".

These responses indicate that there is a good deal of interest in individualized, specific advice on crop protection among Iowa and Illinois farmers, especially in regard to insect control. Growers were about equally divided concerning possible charges for such service. About one-half of them said they would be prepared to pay a fee, while others felt that the information now available for free from pesticide sellers and from the extension service was sufficient.

Some of the more specific information desired by growers may be available at the state university, but is not published. Information on costs and profits of specific pesticides is not available from the university.

b. Information on pesticide side effects.

Side effects from the use of pesticides may occur and become apparent immediately or soon after the use of the pesticide, or they may occur slowly, through sometimes complex chains of events, in such a way that they become apparent only later, often long after the causative pesticide use.

An example of the first type would be damage to a neighboring, susceptible crop from the use of a herbicide. An example of the second type would be the gradual build-up, bioaccumulation and biomagnification of residues of persistent pesticides that, after a period of time, may result in the appearance of high residues in organisms at the tops of food chains, as has been demonstrated in the case of some of the persistent chlorinated hydrocarbon insecticides. There is no clear-cut delineation between these two types of effects and sometimes, both overt and delayed effects may result from the same pesticide use.

Side effects from the use of pesticides that are of concern to farmers include possible interactions between various insect, weed and disease control measures, crop rotation, tillage, cultivation and other soil management practices, soil erosion, profits, and, a newly added concern, farm fuel requirements.

To determine to what extent state universities can or do assist growers in assessing these interactions and in coping with them, we directed the following inquiry to the Deans of the College of Agriculture of the University of Illinois and Iowa State University, respectively:

> "Under a contract funded jointly by the Council on Environmental Quality and the U. S. Environmental Protection Agency (Contract #EQC-325), we are currently studying use patterns of insecticides and herbicides on corn and soybeans in the midwest. We are interested, among other things, in the interactions between the use of insecticides and herbicides, weed and insect damage thresholds, tillage practices, crop rotation sequences, and profit to growers. We are wondering if any tests have been conducted in your state in which these factors may have been studied jointly, in the same field tests, by agronomists, weed scientists, entomologists, and economists. If so, could you please arrange for us to receive copies of reprints or reports on the results?
>
> Regardless of whether or not such multidisciplinary studies have been conducted, we would be interested in

> your views on the feasibility and merits of such an approach. Many agricultural scientists seem to feel that it is best for each discipline to work on its own problems in its own, separate tests, leaving it up to the farmer to put it all together. We wonder to what extent this attitude may arise from traditions, and the organizational structure and teaching responsibilities of land-grant colleges. In any event, we would be very grateful if we could have your comments on the relative merits and demerits of multidisciplinary approaches to the crop protection problems in your state".

A very constructive and thoughtful reply to this inquiry was received from Dr. S. R. Aldrich, Assistant Director of the University of Illinois Agricultural Experiment Station. Among other things Dr. Aldrich describes the problems encountered by researchers in dealing with large numbers of variables in a single experiment. Directly to the point, Aldrich states:

> "In the final analysis, the individual farmer must assume considerable responsibility for fitting pieces together because pre-tailored packages of practices will always have to be too general to fit his particular system".

It appears from other parts of his letter that the university is aware of additional opportunities for interdisciplinary approaches, especially in the field of environmental studies, and that efforts are made to promote more interdisciplinary research and teaching. Interestingly, Dr. Aldrich did not take up the question of studies on the economic consequences of crop protection measures. Nevertheless, his letter presents an excellent overview of the problems at the university level, and of the many steps that are taken to better assist farmers in coping with theirs. For this reason, Dr. Aldrich's letter has been included in its entirety in this report as Appendix C.

Iowa State University replied to the same inquiry in a nutshell format, saying essentially the same as the much more detailed reply from Illinois, including the following:

> "Multidisciplinary research is being increased. One-third of agronomy research projects involve personnel from other disciplines. Ag-engineering and weed science are cooperating on some research this year. Members of the entomology department are working with agronomy on some phases of their research".

Iowa further stated that "no large multidisciplinary research" was underway which would involve agronomists, weed scientists, entomologists and economists in a planned effort. "This probably should be done, but it would be difficult."

These replies indicate that at the present time, there is not much, if any information available to growers from state universities in regard to the interactions between crop protection measures, other agronomic practices, and resulting profits.

Concerning delayed side effects from the use of pesticides, many authors have dealt with the biological and environmental aspects of this problem. Much less attention has been given thus far to the effects of various crop protection strategies on the future profitability of the crop production systems involved or, in other words, to the economic aspects of the problem.

A review of the past history of the use of chemical pesticides indicates that the usefulness of most or all of them is eroded by the development of resistance in the target pest(s), the selection of pest populations that are more difficult to control, and/or the destruction of natural control factors. This erosion process proceeds slowly with some chemicals and some of their uses, quite rapidly with others. Sometimes groups of related chemicals are affected, and a new chemical in such a group may run into resistance problems even before it ever reaches the market.

The typical progression of this erosion process is all to well known. Following highly successful initial use of a given pesticide, succeeding applications begin to work less well. Rates and frequency of application of the pesticide(s) are increased. Next, more potent pesticides are used, but they soon experience the same problem. Costs of controlling target pests rise steadily. Often, problems of residues in treated crops and/or in the environment, and side effects on nontarget organisms also develop and increase. Eventually, the reservoir of still more potent chemicals becomes exhausted, or costs become prohibitive. At this stage, unless alternate control methods are available, growers are left with an unmanageable problem, and the pesticide industry without customers.

A classical case demonstrating this sequence of events has been described by Adkisson (1971). In northeastern Mexico, cotton was intensively dusted and sprayed wiht chlorinated hydrocarbon insecticides, mainly for control of the boll weevil, *Anthonomus grandis*. In the late 1950's, the boll weevil became resistant to chlorinated hydrocarbons, and growers switched to organophosphorus insecticides, primarily methyl parathion. DDT was added to control the bollworm, *Heliothis zea*, and the tobacco budworm, *H. virescens*. Within a few years, the bollworm and tobacco budworm became more important than the boll weevil and, at the same time, both species, especially the tobacco budworm, became increasingly resistant to all insecticides. By the late 1960's, many cotton growers had to treat their fields 15 to 18 times with high rates of methyl parathion and, even then, suffered great yield losses. By 1970, the tobacco budworm had developed such a high level of resistance that severe outbreaks could not be controlled, regardless of the insecticide used. In 1960, about 700,000 acres of cotton were grown in the Matamoros-Reynosa area of northern Mexico. When cotton insect problems first became severe in this area, approximately 500,000 acres of cotton were moved from Matamoros to new land somewhat further south, in the Tampico-Mante area. By 1970, less than 3,000 acres of cotton were raised in both of these areas combined. Adkisson comments on these developments as follows:

> "The seeds for the destruction of the Mexican cotton industry were planted when the producers decided that their insect pest problems could be best solved by the unilateral use of regularly scheduled applications of broad-spectrum insecticides. Hindsight shows that this method of pest control was bound for failure since the genetic diversity of insects is such that they appear capable of evolving strains resistant to all insecticides. Once the tobacco budworm became resistant to all available insecticides, the system failed in Mexico. Thus, it is evident that a different strategy for the control of insect pests of cotton must be devised if the industry is to survive".

This unfortunate experience of Mexican cotton growers is one of the more dramatic, but not the only example of failure of a unilateral chemical pest control strategy. For instance, problems of mites, aphids and other insects on fruit and vegetable crops in certain parts of the United States (as well as in other countries) have taken a very similar course, except that in most instances, disaster was averted by timely adoption of more judicious crop protection strategies, including more judicious use of chemical pesticides.

In the midwest today, failure of the strategies currently employed for the control of corn and soybean insects and weeds does not appear imminent, but several warning signals are in evidence. These include:

-- The use of ever increasing quantities of herbicides and insecticides;

-- The ongoing selection of more resistant target weed and insect strains, species and populations;

-- The continuing increase in the cost of chemical crop protection;

-- Pesticide residue and persistence problems.

These symptoms indicate that corn and soybean insecticides and herbicides are not exempt from this erosion process. The question arises if this escalator cannot be stopped, or at least slowed down, before a crisis stage is reached, and what might be done now to preserve and prolong the usefulness of presently available crop protection tools, including the chemical pesticides currently in use.

Most midwestern farmers are businessmen who are naturally interested in preserving the productivity of their assets. Chemical pesticides are among these assets. However, few if any farmers, and few of the persons advising them on the use of pesticides appear to be aware of hidden future costs inherent in present pesticide use decisions. Greater awareness on the part of pesticide users of how their present crop protection decisions might affect their future profits would appear to be desirable.

For instance, those midwestern farmers to whom we "experimentally" mentioned the Mexican cotton growers' experience were intensely interested in it. Data or projections on how current corn and soybean pesticide use practices might affect the future profitability of these crops would undoubtedly be of even much greater interest. Such data are not available at present, but it may be worthwhile to attempt to generate them. This type of information would probably be a much greater incentive to farmers to use pesticides more judiciously than warnings about ill-defined actual or potential environmental damage.

Returning to the farmers' questions enumerated at the beginning of this discussion (p. 123), the findings and considerations presented in this section suggest that farmers are not adequately informed about side effects that may result from their pesticide use decisions. The term "side effect" is used in a broad sense in this discussion, including especially overt and delayed economic effects. Such information does not appear to be available, at least not in regard to the corn and soybean production systems.

7. Individualized Crop Protection Information

The question how the apparent interest on the part of a substantial number of growers in individualized advice on crop protection might be met was explored with agricutlural research and extension workers, pesticide industry representatives, and other knowledgeable persons both in the midwest and elsewhere. The subject was also discussed at length during the meeting with project consultants from Iowa, Illinois and Missouri at Davenport, Iowa, in January of 1974. Considerable uncertainty and differences of opinion were evident in these discussions.

Pesticide industry representatives are caught in a dilemma. As documented in other parts of this report, the pesticide trade has thus far been the predominant source of pesticide information for growers. Many individuals in all echelons of the pesticide industry are very receptive to the idea of shifting emphasis from the selling of pesticides to the selling of crop protection. However, the proposition to provide services instead of chemicals, rather than in support of the sale of chemicals, is quite foreign to the basic policies and philosophies of many chemical companies. For most representatives of the pesticide indsutry who work where the "rubber hits the road", rewards such as raises, promotions, Christmas bonuses and/or commissions still appear to be geared to sales volumes in terms of quantities.

Most (but not all) extension workers believe that it is beyond the scope of the federal/state cooperative extension service to furnish specific crop protection advice to individual growers on a regular basis. They point out that the extension service does not have the personnel to check more than a limited number of fields on an irregular basis and suggest that there may be a need for independent, private-enterprise crop protection consultants. The question is whether such enterprises would find sufficient economic incentives in working on insect and weed problems of midwestern field crops.

Farmers in our survey expressed more interest in advice on insect than on weed control. As pointed out in Chapter IV, corn soil insecticides are applied only once per season in the majority of cases, and the cost of the insecticide is only about $2.00 to 4.00/acre (Table 10). Thus, avoidance of unnecessary insecticide applications will not result in large dollar savings, while the use of an insecticide when needed is quite profitable (Table 13). Control of soybean insects has not been a regular problem in Iowa and Illinois in the past. Here again, the insecticide cost is only about $1.00 to 2.00/acre/treatment.

Under these circumstances, handling of corn and soybean insect control problems alone would probably not offer a viable economic basis for private crop protection entrepreneurs. One solution suggested was that individualized crop protection advice might be provided as part of a "package deal" that would also include advice on fertilizers, seeds, irrigation, etc., at least in the beginning.

These opinions are supported by the fact that up to the present, no private crop protection consultants are known to be operating in Iowa or Illinois. We therefore extended a search for such enterprises to neighboring states and discovered only one, i.e., a company serving growers in southwestern Nebraska and, through another office, in Arizona. Services offered are as follows:

-- Feed lot and materials handling systems design;
-- Irrigation pump and well evaluation;
-- Soil fertility services;
-- Foreign consulting;
-- Data processing service;
-- Irrigation scheduling services;
-- Insect and disease control;
(Note: Weed control not mentioned!)
-- Research and development.

The professional staff of this organization includes five engineers, one soil scientist, one data processing manager, and four "agricultural specialists" with training and experience in agronomy or general agriculture.

The company hires scouts to survey clients' fields to determine irrigation and soil fertility needs and, at the same time, insect and disease levels.

Private-enterprise crop protection (or pest management) consultants who specialize in crop protection alone are operating successfully in other parts of the country, especially in California and the Southwest, some also in the "Cotton South". In addition to cotton, crops serviced include citrus and pome fruits, grapes, walnuts, almonds, tomatoes; and fly and/or bird problems in cattle feed lots, dairies, poultry farms, etc. All of these situations differ from the current problems of weed and insect control on midwestern field crops in at least two important aspects:

(1) They involve crops whose cash value is much higher than that of corn and soybeans;

(2) Target pests (especially insects and phytophagous mites) developed such high degrees of resistance that control by "conventional" use of chemical insecticides became increasingly impractical or impossible, making the adoption of other crop protection strategies an economic necessity.

In these areas, crop protection or pest management consultants, being a part of the alternate crop protection strategies required, provided and continue to provide a service for which there is a clear economic need.

In the midwestern field crop situation, comparable economic incentives for private-enterprise crop protection advisers do not exist at present because chemical crop protection methods are still quite economical, especially if possible hidden future costs are disregarded. This situation may change if the cash value of corn and soybeans continues to increase, and/or if the usefulness and economy of the presently used chemical pesticides continues to erode.

It would seem highly desirable to attempt to slow down this erosion process before it reaches critical proportions. Providing growers with the type of specific, individualized advice on the use (or nonuse) of pesticides in which many of them expressed interest would appear to be one important step in this direction. As more information on economic and other side effects from the unilateral use of pesticides becomes available, this should also be made available to growers speedily in order to provide them with a better base for crop protection decisions.

C. Summary

Farmers in Iowa and Illinois receive information on pesticides primarily from pesticide sellers, pesticide labels, and other farmers. University extension specialists, area extension agents and county agents (farm advisors) are regarded by farmers as very useful sources of information on pesticides. They are very effective communicators, considering their small numbers in relation to the large number of farmers they serve. However, these public servants are outnumbered by pesticide industry representatives and sellers by such wide margins that their messages reach a much smaller percentage of growers directly.

Extension publications, meetings and field demonstrations likewise do not reach a significant percentage of growers directly. The pesticide trade is the largest clientele for these communications outside of the university and extension system itself. Extension publications are also sent to news media such as farm magazines, newspapers, radio, and TV stations and are reproduced by these media in whole or in part. However, this does not significantly increase the flow of information to farmers because they do not think highly of these media as sources of pesticide information.

These pesticide information flow patterns developed during a period when the objectives of the pesticide trade were largely in harmony with those of federal and state agencies. In the past, the development and increased use of pesticides were generally promoted by both groups. Messages recommending reduced or no use of pesticides will not flow well through this communications system.

Insect and weed control recommendations published by the Iowa and Illinois extension services provide growers with little information on the specific advantages and disadvantages of individual pesticides, and with no information on costs or profits. The Iowa weed control recommendations do not include dosage rates. Entomologists and weed scientists interviewed realize that this leaves growers without an unbiased source of advice on the economics of their pesticide choices, but feel strongly that they (public agency personnel) should not become involved with the cost and profit aspects of individual pesticides.

Many of the farmers interviewed expressed interest in receiving individualized, specific advice on crop protection, especially in regard to insect control. About one-half of the respondents stated that they would be willing to pay a fee for such a service (ranging from $0.05 to $5.00/acre, averaging about $0.75/acre), while the other half felt that the information now available without charge *from pesticide sellers and from the extension service was sufficient.*

Practically no information is available to growers on possible side effects from the use of pesticides over the long term, or on interactions between various insect, weed, and disease control measures; crop rotation, tillage, cultivation and other agronomic practices; soil erosion; profits; and (a newly added concern) farm fuel requirements. Tackling these problems would require systematic interdisciplinary studies which, at least up to the present, universities or other agricultural agencies in the area have not mounted.

In this connection, it is important to consider that in intensive agriculture such as the midwestern corn/soybean production system, heavy applications of chemical pesticides and fertilizers are made to the same land year after year. Most of these chemicals remain in the upper 1-3 inches of topsoil, and their routes and rates of degradation under field conditions are often not known. It is surprising and somewhat alarming how little information is available on the individual or collective effects of these chemicals on the soil microflora and -fauna and on the long-term fertility of the topsoil, one of our most important resources.

The history of the use of chemical pesticides in other crop production systems indicates that the usefulness of most or all of them is eroded by the development of resistance in the target pest(s), the selection of hardier pest populations, the destruction of natural pest suppression factors, etc. In the midwest today, biological or economic failure of unilateral reliance on corn and soybean pesticides does not appear imminent, but there are warning symptoms, including the use of steadily increasing quantities of pesticides; the progressive selection of more resistant target pest strains, species and populations; the continuing increase of the cost of chemical crop protection; and pesticide residue and persistence problems.

One important step toward slowing this erosion process may *be to provide growers with more specific, individualized advice on the more judicious use (or nonuse) of pesticides. Some of the information needed by growers is available from public agency sources, some of it would have to be adapted to local conditions. However, there are currently no effective, unbiased communication channels through which growers could receive such information regularly and in a timely fashion.*

Private enterprise crop protection (or pest management) consultants operate successfully in other parts of the country on crops whose cash value is much higher than that of corn and soybeans (for instance, cotton; fruit, nut and vegetable crops). At the present time, it is questionable whether private entrepreneurs specializing in crop protection only would find a sufficient economic base in the midwestern corn/soybean economy. The pesticide industry does not appear to be actively interested in providing crop protection services instead of chemicals, rather than in support of the sale of chemicals. Most extension workers believe that it would be beyond the scope of their system to provide specific crop protection advice to growers on a regular basis. It thus appears that the question on how crop protection information can be communicated from state universities to midwestern growers more effectively and without bias merits attention.

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XI. RESOURCES AND METHODS

A. Project Consultants

An outstanding panel of consultants assisted the RvR project team in this study. Members of this panel were:

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Advice and assistance from these consultants were sought and obtained frequently throughout the duration of this study in personal visits, by telephone, and by mail. In addition, "Preliminary results and conclusions" of the study in a nutshell format were mailed to all consultants early in January of 1974, for their review and critique. All consultants except Dr. Metcalf who was unfortunately prevented from attending, then convened for a project meeting with Dr. von Rümker at Davenport, Iowa on January 24-25, 1974. At that meeting, the preliminary results and conclusions and all other aspects of the project were reviewed and thoroughly discussed.

All comments and leads received from all consultants throughout the study and at the Davenport meeting have been carefully considered, followed up, and, where appropriate, incorporated into the final report.

Thus, these consultants made major contributions to the project and, in addition, provided considerable encouragement to the project team. We acknowledge these contributions with much appreciation and gratitude.

B. Survey of Iowa and Illinois Farmers

The backbone of this study is a survey of farmers in Iowa and Illinois that was carried out in several phases.

1. Development of the Question Form.

Firstly, a question form for the farmer interview was drafted, tried out on a grower, re-drafted, and submitted for critique to the project consultants. Written, verbal or telephone comments were received from all of them except Dr. Headley who was still abroad at that time. In addition, helpful comments and advice on the draft form were received in discussions of the form with Dr. H. B. Petty, Jr., Extension Entomologist; Dr. E. L. Knake, Extension Weed Specialist; Dr. J. F. Evans, Agricultural Communications Specialist; Dr. F. C. Fliegel, Rural Sociologist;

Mr. F. M. Sims, Farm Management Extension Specialist; Dr. C. R. Taylor, Agricultural Economist; all at the University of Illinois, Urbana; and from Dr. R. D. Hickman, Associate Professor of Sampling and Survey Methods, Iowa State University, Ames. All of these comments from eleven experts, representing both Iowa and Illinois, and a variety of disciplines and viewpoints, were incorporated into the final version of the question form, Appendix A. In addition, three pages of "Notes for Interviewers" (Appendix B) were prepared to provide interviewers with necessary background information, definitions, etc.

2. The Iowa Farmer Survey

In cooperation with Dr. R. D. Hickman, Statistical Laboratory, Iowa State University, and members of the Department of Entomology and Agronomy at Iowa State University, it was decided to center the Iowa phase of the farmer survey in four counties in northcentral Iowa (Cerro Gordo, Franklin, Hancock, and Wright), an area of intensive corn and soybean production. It was further decided to limit the survey to farmers operating at least 320 acres. About 25% of all farms in Iowa are larger than 320 acres, and more than 50% of the state's cropland area is in farms in this category. Thus, by focusing the survey on larger operators, we obtained information on a larger share of the total cropland acreage than would have been obtained otherwise. Furthermore, studies by Beal and Bohlen (1957) and others indicate that larger farmers are the innovators and opinion leaders whose attitudes and actions are subsequently followed and adopted by smaller operators. This was a second important reason for focusing the survey on larger operators.

A total of 50 to 60 interviews were desired for the Iowa phase of the farmer survey, in keeping with the financial, manpower and time resources available for the entire project.

Using materials especially constructed for the purpose of sampling in rural areas, personnel of the Statistical Laboratory at Iowa State University selected an area sample expected to yield about 70 eligible farm operators, thus allowing a margin for sampling error and for nonresponse. The overall sampling rate was approximately 1 out of 22.6. This rate was applied separately to the sampling materials in each county.

In each county, the sampling was carried out in three stages. In the first stage, two "blocks" (a technical term relating to the sampling materials but roughly equivalent to a township) were selected with probabilities proportional to their sizes in terms of estimated total number of farms. Within each sample block, four so-called count units were selected in a systematic manner with probabilities proportional to their sizes. Finally, by means of dot maps, sample count units were subdivided into smaller areas. These were sampled at a rate such that the product of the selection probabilities at all three stages was equal to the desired overall sampling rate of 1 out of 22.6.

The areas selected at the final stage of sampling were shaded in color on county highway maps. To the extent possible, identifiable boundaries (such as roads or section lines) were used to define the areas. In some cases it was necessary for the field worker to follow prescribed procedures utilizing automobile odometers in order to determine the boundary. Once the boundaries were located, all eligible operators living within the specified area were to be included in the sample. Every eligible farm operator living in the open country (that is, living outside the corporate limits of towns and cities) in the four counties cited previously had the same chance of being selected in the sample.

In late August of 1973, farm operators in the designated sampling areas were personally contacted, and completed interviews were obtained from 58 eligible farm operators. This required 2 weeks' work by a team led by Mr. L. E. Bailey.

3. The Illinois Farmer Survey

In the Iowa survey, the interview questions were presented to a number of interviewees with minimum guidance from the interviewer in order to identify possible misunderstanding of questions, and to determine how the questions might be handled were they presented by mail. Indications were that the question form could very well be handled by mail.

We then conferred with project consultants at the University of Illinois, Urbana, and with members of the Agricultural Economics Department. At their suggestion, we contacted Dr. C. H. Sandage of the Farm Research Institute at Urbana, a small organization that is administratively independent of the University, but cooperates in many of its projects. Dr. Sandage, President of the Farm Research Institute, is a recognized expert in farmer surveys in the Midwest. Dr. Sandage agreed with our opinion that the question form was well suited to use by mail.

Considering the production patterns of corn and soybeans in Illinois in relation to geography (Figures 1 and 2), it was decided to eliminate the southern third of the state from the survey. Through the Farm Research Institute, question forms were then mailed to 253 farmers operating 320 acres or more in central and northern Illinois. This sample consisted of all farmers eligible by virtue of farm size and geographical location out of a standing panel of about 900 farmers. 239 completed interviews were obtained by the deadline date in October of 1973, a 94.5% response. Every county in the northern two-thirds of Illinois is represented among the 239 respondents, giving us a complete scatter of responses from the desired area.

4. Tabulation and Analysis of the Survey Results

The completed question forms from both the Iowa and Illinois farmer surveys were then tabulated by RvR personnel. Each question form includes a total of 149 information items. Thus, a total of almost 45,000 information items were processed. The raw tabulated data were then carefully analyzed, summarized and evaluated, and comparisons were made with previous studies pertinent to the objectives of this project. These comparisons are included in the body of the report.

It is noteworthy that the results of our survey were in good agreement with the results of several major previous surveys in cases where the surveys contained comparable questions. This lends support to the findings in our survey and, in several instances, permitted extension of trends (examples: Tables 17, 18, 21, 26).

C. Previous Studies

Our search of the literature and of the state of the art in the early phases of this project revealed a number of previous farmer and related surveys that were applicable to the objectives of this project in whole or in part. The results of these previous studies have been discussed in the body of this report and were considered in arriving at findings and conclusions. Complete references to these studies are included in the literature reference section, under the respective authors' or originators' names. Studies in this category include the following:

Beal et al. (1966)
Beal et al. (1969)
Beal and Bohlen (1957)
Hestand et al. (1971)
Illinois Cooperative Crop Reporting Service (1973b)
Inter/Agriculture (1970, 1971)
Kerr (1970)
Petty (1974)
Prairie Farmer (1970, 1972)
Smith and Heady (1970)
Thomas and Evans (1963)
U. S. Department of Agriculture(1968a, 1970b, 1972b, 1974)
Wallaces Farmer (1970, 1971)

D. Other Contacts

A fourth important resource used extensively in this project consisted of numerous personal, correspondence and/or telephone contacts with the following groups:

- Federal/State Cooperative Extension administrators, specialists, and area and county agents;
- State University agronomists; agricultural economists; agricultural engineers; entomologists; plant pathologists; rural sociologists; statisticians; survey specialists; and weed scientists;
- Pesticide manufacturers, wholesalers, retailers, and sales representatives;
- State government officials dealing with pesticide problems;
- Private agricultural consultants;
- Other knowledgeable persons.

A list of the individuals whom we contacted in the course of this project follows. We gratefully acknowledge all contributions of information, advice and comments from these persons.

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University of Arizona
Tucson, Arizona

RvR Project #53/Farm Survey 1973 Form #

SECTION A: GENERAL

1. How many acres of land (including all crops, pastures, diverted acres, farmstead, etc.) do you operate this year? ___________

2. How many acres of corn are you growing this year? ___________

3. What is the crop rotation sequence of your 1973 CORN acreage?

   a/ ___________ acres corn on corn

   b/ ___________ acres corn on soybeans

   c/ ___________ acres corn on sod or pasture

   d/ ___________ acres corn following another crop

4. How many acres of soybeans are you growing this year? _______

5. What is the crop rotation sequence of your 1973 SOYBEAN acreage?

   a/ ___________ acres soybeans on soybeans

   b/ ___________ acres soybeans on corn

   c/ ___________ acres soybeans following another crop

6. Do you plan to grow more ( ), fewer ( ), or about the same ( ) number of acres of corn in 1974, or are you undecided ( ) at this time? (Check one.)

7. Do you plan to grow more ( ), fewer ( ), or about the same ( ) number of acres of soybeans in 1974, or are you undecided ( ) at this time? (Check one.)

8. Is any of your land:

   a/ suitable for terracing? _______(yes or no)

   b/ If yes, about how many acres are suitable for terracing? _______

   c/ How many acres (if any) are actually terraced? _______

9. In your corn and/or soybean growing operations, do you use:

   a/ conventional tillage (plowing, disking)? _______(yes or no)

   b/ minimum tillage (till-planting, mulch tillage, etc.)? _______(yes or no)

   c/ no till (zero tillage, slit, slot, sod planting, etc.)? _______(yes or no)

10. Which of the following sources of information did you use in 1973 and/or 1972 in deciding if, when and how to use herbicides (weed killers), insecticides (insect killers), or other chemical pesticides, which product to use, what rate of application, etc.? How useful was the information from each source that you used? Please be sure you check "Yes" or "No" for each source, and indicate your degree of satisfaction with each source for which you answered "yes."

Source	Used source (Check yes or no)		If yes, was the information you received		
	Yes	No	Very good	Satisfactory	Unsatisfactory
a/Chemical retailer	( )	( )	( )	( )	( )
b/Representative of chemical mfg.	( )	( )	( )	( )	( )
c/Sales leaflets, etc.	( )	( )	( )	( )	( )
d/Label ou chemical container	( )	( )	( )	( )	( )
e/Farm magazines	( )	( )	( )	( )	( )
f/Newspapers	( )	( )	( )	( )	( )
g/TV	( )	( )	( )	( )	( )
h/Radio	( )	( )	( )	( )	( )
i/Other publications	( )	( )	( )	( )	( )
j/County agent/Farm Adviser	( )	( )	( )	( )	( )
k/Area extension agent	( )	( )	( )	( )	( )
l/University extension specialist	( )	( )	( )	( )	( )
m/Neighbors, friends, relatives	( )	( )	( )	( )	( )
Meeting or field demonstration conducted by:					
n/State/University	( )	( )	( )	( )	( )
o/Chemical producer or seller	( )	( )	( )	( )	( )

11. State University and/or Federal insect and weed control specialists in your state conduct field tests each year to find out which products work best for the control of weeds and insects in different areas, and when and how much to apply for best results.

a/Did you personally visit such field tests during the last 3 years? ________(yes or no)

b/If yes, how many field tests did you see during the last 3 years? ________

c/Were the tests you saw during the last 3 years run by Federal, State, University or County personnel ( ), or by pesticide companies or retailers ( )? (Check one or both.)

d/Did you receive the results of such tests in written form? ________(yes or no)

e/If you have not received such test reports in the past, would you like to receive them in the future? ________(yes or no)

10. **Which of the following sources of information did you use in 1973 and/or 1972 in deciding if, when and how to use herbicides (weed killers), insecticides (insect killers), or other chemical pesticides, which product to use, what rate of application, etc.? How useful was the information from each source that you used? Please be sure you check "Yes" or "No" for each source, and indicate your degree of satisfaction with each source for which you answered "yes."**

Source	Used source (Check yes or no)		If yes, was the information you received		
	Yes	No	Very good	Satis-factory	Unsatis-factory
a/Chemical retailer	( )	( )	( )	( )	( )
b/Representative of chemical mfg.	( )	( )	( )	( )	( )
c/Sales leaflets, etc.	( )	( )	( )	( )	( )
d/Label on chemical container	( )	( )	( )	( )	( )
e/Farm magazines	( )	( )	( )	( )	( )
f/Newspapers	( )	( )	( )	( )	( )
g/TV	( )	( )	( )	( )	( )
h/Radio	( )	( )	( )	( )	( )
i/Other publications	( )	( )	( )	( )	( )
j/County agent/Farm Adviser	( )	( )	( )	( )	( )
k/Area extension agent	( )	( )	( )	( )	( )
l/University extension specialist	( )	( )	( )	( )	( )
m/Neighbors, friends, relatives	( )	( )	( )	( )	( )
Meeting or field demonstration conducted by:					
n/State/University	( )	( )	( )	( )	( )
o/Chemical producer or seller	( )	( )	( )	( )	( )

11. State University and/or Federal insect and weed control specialists in your state conduct field tests each year to find out which products work best for the control of weeds and insects in different areas, and when and how much to apply for best results.

a/Did you personally visit such field tests during the last 3 years? ________(yes or no)

b/If yes, how many field tests did you see during the last 3 years? ________

c/Were the tests you saw during the last 3 years run by Federal, State, University or County personnel ( ), or by pesticide companies or retailers ( )? (Check one or both.)

d/Did you receive the results of such tests in written form? ________(yes or no)

e/If you have not received such test reports in the past, would you like to receive them in the future? ________(yes or no)

12. Assume a competent crop protection advisory service would give you precise information (by mail, telephone, radio, etc.), based on insect and weed counts, soil properties, etc., on which herbicides and insecticides to use (by product name); the amount to use per acre; and the date the product or products should be applied for best results.

a/Would you follow the advice? ________(yes or no)

b/If the service would advise that some or all of your fields do not need treatment because insect or weed infestations are too low for treatments to be worthwhile, would you follow the advice? ________(yes or no)

c/If a fee would have to be charged for such a service, how much would you be willing to pay per acre? $________

SECTION B: WEED CONTROL ON CORN

13. Did you use one or more chemical herbicides (weed killers) on your corn in 1973? ________(yes or no)

If no, answer the following questions for 1972. If you did not use corn herbicides in 1972 either, skip this section and go to question 25.

14. Name the product or products used (in decreasing order of quantity used):

____

____

15. Did you use the same single product or combination of products in 1972? _____ 1971? _____ 1970_____? (Answer yes or no for each year.)

16. If no, a/ why did you switch products? ________________________

____

b/ On whose advice did you switch products? ________________________

17. During the last 5 years, has your cost (dollars per acre) for chemical herbicides on corn:

increased?________(yes or no) If yes, about how much? ________%

decreased?________(yes or no) If yes, about how much? ________%

remained about the same? ______________(yes or no)

18. Indicate which of the following statements best describe the results of your use of corn herbicides this year and last year.

For each year, check a, b or c; and d, e or f.

		1973	1972
Check one for each year	a/Corn nearly weed-free	( )	( )
	b/Weeds suppressed sufficiently to prevent yield loss	( )	( )
	c/Weed control unsatisfactory	( )	( )
Check one for each year	d/Money for corn herbicides was well spent	( )	( )
	e/Money for corn herbicides was wasted	( )	( )
	f/Should have spent more money for corn herbicides	( )	( )

19. Do all of your corn acres need chemical herbicides each year? ________(yes or no)

20. If no, do you treat only the weedy areas ( ), or treat all corn acres regardless ( )? (Check one.)

21. Compared to the mid-1960's, do the corn herbicides that you use today (this year or last year) give you better ( ) or poorer ( ) weed control? (Check one.)

22. What benefits do you obtain from using herbicides on corn? (Check one or more, and/or describe benefits not listed.)

a/Save labor ( )
b/Facilitate planting ( )
c/Control weeds ( )
d/Good-looking fields ( )
e/Save cultivating ( )
f/Save other tilling operations ( )
g/No benefits ( )
h/Other benefits ( ), please describe: ________

23. Assume the cost of all corn herbicides were twice as high as what you actually paid this year:

a/would you still use the product or products you used this year in the same amounts and on the same number of acres of corn? ________(yes or no)

b/If no, what would you do instead? ________

24. Assume all corn herbicides would be removed from the market or become ineffective against corn weeds:

a/would you continue to grow corn? ________(yes or no)

b/If yes, how would you control weeds? ________

c/If no, what other crop or crops would you grow instead of corn? ________

SECTION C: INSECT CONTROL ON CORN

25. Did you use one or more chemical insecticides (insect killers) on your corn in 1973? ________(yes or no)

If no, answer the following questions for 1972. If you did not use corn insecticides in 1972 either, skip this section and go to question 35.

26. Name the product or products used (in decreasing order of quantity used): ________

27. Did you use the same single product or combination of products in 1972? ________ 1971? ________ 1970? ________ (Answer yes or no for each year.)

28. If no, a/why did you switch products? ________

b/On whose advice did you switch products? ________

29. During the last 5 years, has your cost (dollars per acre) for chemical insecticides on corn:

increased? ________(yes or no) If yes, about how much? ________%
decreased? ________(yes or no) If yes, about how much? ________%
remained about the same? ________(yes or no)

30. Indicate which of the following statements best describe the results of your use of corn insecticides this year and last year.

For each year, check a, b or c; and d, e or f.

		1973	1972
check one for each year	a/Corn suffered no insect damage whatsoever	☐	☐
	b/Insects suppressed sufficiently to prevent yield loss	☐	☐
	c/Insect control unsatisfactory	☐	☐
check one for each year	d/Money for corn insecticides was well spent	☐	☐
	e/Money for corn insecticides was wasted	☐	☐
	f/Should have spent more money for corn insecticides	☐	☐

31. Do all of your corn acres need chemical insecticides each year? ________(yes or no)

32. If answer is no, how do you decide which corn acres to treat and which not?

33. Assume the cost of all corn insecticides were twice as high as what you actually paid this year:

a/would you still use the product or products you used this year in the same amounts and on the same number of acres of corn? ________(yes or no)

b/If no, what would you do instead? ________

34. Assume all corn insecticides would be removed from the market or become ineffective against corn insects:

a/would you continue to grow corn? ________(yes or no)

b/If yes, what would you do to minimize insect damage? ________

c/If no, what other crop or crops would you grow instead of corn? ________

SECTION D: WEED CONTROL ON SOYBEANS

35. Did you use one or more chemical herbicides (weed killers) on your soybeans in 1973? ________(yes or no)

If no, answer the following questions for 1972. If you did not use soybean herbicides in 1972 either, skip this section. Interview is completed.

36. Name the product or products used (in decreasing order of quantity used):

37. Did you use the same single product or combination of products in 1972? ________ 1971? ________ 1970? ________ (Answer yes or no for each year.)

38. If no, a/why did you switch products? ____________________

____

b/On whose advice did you switch products? ____________________

39. During the last 5 years, has your cost (dollars per acre) for chemical herbicides on soybeans:

increased? ________(yes or no) If yes, about how much? ________%
decreased? ________(yes or no) If yes, about how much? ________%
remained about the same? ____________________(yes or no)

40. Indicate which of the following statements best describe the results of your use of soybean herbicides this year and last year.

For each year, check a, b or c; and d, e or f.

		1973	1972
check one for each year	a/Soybeans nearly weed-free	( )	( )
	b/Weeds suppressed sufficiently to prevent yield loss	( )	( )
	c/Weed control unsatisfactory	( )	( )
Check one for each year	d/Money for soybean herbicides was well spent	( )	( )
	e/Money for soybean herbicides was wasted	( )	( )
	f/Should have spent more money for soybean herbicides	( )	( )

41. Do all of your soybean acres need chemical herbicides each year? ________(yes or no)

42. If no, do you treat only the weedy areas ( ), or treat all soybean acres regardless ( )? (Check one.)

43. Compared to the mid-1960's, do the soybean herbicides that you use today (this year or last year) give you better ( ) or poorer ( ) weed control? (Check one.)

44. What benefits do you obtain from using herbicides on soybeans? (Check one or more, and/or describe benefits not listed.)

a/Save labor ( )
b/Facilitate planting ( )
c/Control weeds ( )
d/Good-looking fields ( )
e/Save cultivating ( )
f/Save other tilling operations ( )
g/No benefits ( )
h/Other benefits ( ), please describe:

____

45. Assume the cost of all soybean herbicides were twice as high as what you actually paid this year:

a/would you still use the product or products you used this year in the same amounts and on the same number of acres of soybeans? ________(yes or no)

b/If no, what would you do instead? ____________________

____

46. Assume all soybean herbicides would be removed from the market or become ineffective against soybean weeds:

a/would you continue to grow soybeans?________(yes or no)

b/If yes, how would you control weeds? ____________________

____

c/If no, what other crop or crops would you grow instead of soybeans? ____________________

____

Appendix B

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ROSMARIE VON RÜMKER, SC. D.

20 August 1973

RvR Project #53/Farm Survey

Notes for Interviewers.

The term "pesticides" includes insecticides (insect killers), herbicides (weed killers), fungicides (fungus killers), nematicides, miticides, rodenticides, and other substances that will destroy or repel pests, or offer protection from pests. "Pests" are unwanted animals, plants, or viruses which cause injury, disease or destruction to desirable plants, animals, structures, goods, or to man himself. Forms of life which may be pests include insects, weeds, fungi, bacteria, viruses, nematodes, mites, rodents, snails, slugs, birds, and other organisms.

In this project, we are primarily interested in the insects and weeds that attack corn and soybeans.

The background and purpose of this study are outlined in the attached 2-page Project Summary ("Introduction" and "Objectives").

The following comments will serve to further explain certain individual questions.

Question 1: "How many acres (all crops combined) do you farm this year?" Include all acres farmed, including pastures, diverted acres, etc.

Questions 3 and 5, concerning crop rotation sequences for the corn and soybean acreage, this information is important to the project because weed and insect problems vary somewhat, depending upon the preceding crop. For instance, in corn on corn, corn rootworms tend to be a problem; in corn on sod or pasture, other soil insects are sometimes abundant.

Question 8: Terracing reduces soil erosion and thus possible water pollution from pesticide residues in the soil. For this reason, terracing practices are of interest to us in this project.

RvR Project #53/Farm Survey

Notes for Interviewers Continued

Question 9: "In your corn and/or soybean operations, do you use (a) Conventional tillage; (b) Minimum tillage; or (c) No till?" The different tillage systems in this question are defined as follows:

a/Conventional tillage includes primary and secondary tillage operations normally performed in preparing a seedbed for a given crop. One of these operations usually is plowing.

b/Minimum tillage is the minimum soil manipulation necessary for crop production. Minimum tillage includes all systems with fewer tillage operations than conventional tillage. Often, substitute techniques such as the use of herbicides are employed for weed control and/or seedbed preparations. Examples of minimum tillage systems are:

--Till-planting, a strip tillage system in which sweeps cut and remove residue, growing vegetation and a layer of soil over the row (generally one-third of the row width) ahead of surface planters in a once-over operation.

--Mulch-tillage, also referred to as stubble mulching, is tillage or preparation of the soil in such a way that plant residues or other materials are left to cover the surface both before and after crop establishment.

c/No-till, also called no tillage, slit plant, slot plant, sod plant, or zero tillage, is a system whereby a crop is planted directly into a seedbed untilled since harvest of the previous crop.

We are interested in tillage systems in this project because different tillage practices affect pesticide requirements. They may also affect soil erosion. Soil that may be transported away from a field in the process of erosion may carry pesticide residues. Thus, different tillage practices have an influence on environmental pollution, especially water pollution, by pesticides.

Question 12. c: Possible fee for crop protection advisory service. If interviewee has difficulty answering this question, interviewer may mention that possible fees might be of the order of $0.80 - 1.50 per acre of all crops to be placed under such a program (not per acre of all land in the farm).

RvR Project #53/Farm Survey

Notes for Interviewers Continued

Section B: Weed Control on Corn
Section C: Insect Control on Corn
Section D: Weed Control on Soybeans

Questions 14, 15 and 16)
Questions 26, 27 and 28)
Questions 36, 37 and 38)- The purpose of these three questions is not to determine exactly what pesticides were used in what quantities. Therefore, we need only an approximate order of magnitude in response to questions 14, 26 and 36. What we really want to know is if the farmer made a change in the pesticides used during the last four years and if so, why. Thus, questions 16, 28 and 38 are the most important ones in this sequence, and the two preceding questions are intended merely to lead up to them. In obtaining answers to questions 16, 28 and 38, try to determine which of the information sources in question 10, page 2 prompted the farmer to switch products.

Question 34, b: "What would you do to minimize insect damage if all corn herbicides would be removed from the market or become ineffective against corn insects?" Interviewer should first attempt to get an answer from the farmer without making any suggestions. If farmer has difficulty answering the question, interviewer may suggest steps that might be taken in this situation, such as avoid growing corn on corn to avoid corn rootworm damage; avoid growing corn on sod to avoid damage from other soil insects; select corn variety resistant or tolerant to insect damage, etc.

RvR Project #53
Funded jointly by the Council on Environmental Quality
and the U. S. Environmental Protection Agency, Contract #EQC-325

Title: "Farmers Pesticide Use Decisions and Attitudes on
Alternate Crop Protection Methods"

I. Introduction.

Crop yield losses due to pests including insects, weeds, diseases, nematodes, and other organisms reduce farming profits. Modern agricultural production techniques such as growing large, continuous stands of one crop in succession (monoculture), use of high yielding crop varieties, irrigation, use of fertilizers, etc., tend to increase potential crop losses due to pests, and thus the incentive to prevent such losses. Since the advent of the synthetic organic pesticides, farmers have relied increasingly on the use of these chemicals for the protection of their crops.

In many instances, chemical pesticides provided spectacular control of target pests when they were first introduced. However, fairly soon, undesirable results also appeared, including the development of pest strains resistant to pesticides; increasingly rapid resurgence of target pest populations following treatments; outbreaks of secondary pests which did not cause economic damage previously; adverse effects on wildlife; and undesirable residue levels on food crops, in human tissues, and in many other elements of the environment. There is increasing concern about possible effects of long-term exposure to low levels of pesticides, alone or in conjunction with other stresses, on many forms of life, including man himself.

Farmers use pesticides for economic reasons, i.e., to prevent profit losses resulting from crop yield losses. This proposal deals with the factors that enter into farmers' pesticide use decisions, and with farmers' attitudes in regard to alternate crop protection strategies. It is suggested that this investigation be focused on the two most important U.S. field crops (in terms of acreage and cash value), corn and soybeans. A large and continually increasing acreage of these crops currently receives applications of chemical pesticides at increasing frequencies and dosage rates. It is estimated that in 1972, at least 35 million acres of corn and soybeans combined received one or more treatment(s) with one or more pesticide(s).

There is growing concern among entomologists, weed specialists, agromonists, economists, and ecologists about the biological and economic wisdom of indefinite continuation of the present pesticide use patterns on these (and other) crops. Alternate loss prevention strategies to be studied in this project that would contribute to a reduction in the use of chemical pesticides, or at least in breaking the present trend of rapidly increasing use of pesticides, would have large potential benefits in view of the large acreages and large quantities of pesticides involved.

II. Objectives.

The basic objective of this project is to study the factors that farmers consider in making pesticide use decisions, and farmers' knowledge of, and opinions on possible alternatives to the use of chemical pesticides. Such information is needed for the development of crop protection strategies alternative to sole reliance on chemical pesticides. To accomplish this objective, questions to be studied include the following:

How do farmers arrive at pesticide use decisions? What information sources do farmers rely on in making these decisions? How reliable are these sources? Are they biased?

To what extent do farmers apply pesticides on preventive, pre-programmed application schedules, and to what extent only after an actual need has been established?

What is the normal degree and extent of infestation of the pest(s) against which the chemical pesticide(s) are used (economically damaging level of infestation; percentage of total crop acreage likely to be affected)?

Which pesticide use patterns are most wasteful (high rate of preventive use against pest(s) occurring infrequently or affecting only a small percentage of the total acreage)?

Would farmers make different pesticide use decisions if they had

-- more information on alternatives?
-- reliable forecasts on the level of pest infestations and damage likely to occur in a given season?
-- more complete data on the present and future costs of their present pesticide use patterns, compared to the present and future costs of alternatives?

What other information or incentives (positive or negative) might cause farmers to reduce or eliminate wasteful pesticide use practices, and to use minimum needed, rather than maximum tolerated amounts of chemical pesticides?

UNIVERSITY OF ILLINOIS

Appendix C

AGRICULTURAL EXPERIMENT STATION 109 MUMFORD HALL, URBANA, ILLINOIS 61801 TELEPHONE (217) 333-0240

OFFICE OF DIRECTOR

October 22, 1973

Dr. Rosmarie von Rümker
RVR Consultants
P. O. Box 553
Shawnee Mission, Kansas 66201

Dear Dr. von Rümker:

Dean Bentley asked me to respond to your request for information on multidisciplinary studies on insecticides and herbicides. I requested assistance from several staff members, hence the delay in responding.

I feel there is close liaison among research and extension workers to the end that appropriate interdisciplinary considerations are recognized and frequently, though certainly not always, researched. The following paragraphs illustrate how multidisciplinary research evolves in the area of corn production.

The nature of agricultural field research is that one first attempts to thoroughly understand the principles involved. This is best accomplished by studying one factor at a time for example herbicides on corn. Later the researcher usually hypothesizes that there are interactions among certain practices which must be field tested because they are not fully predictable on theoretical grounds alone. Such studies often begin within the expertise of one researcher or a single department, for example the combined effect of date of planting, plant population and cultivation on weed problems and utility of various herbicides. At some point the researcher, if he has proper liaison with other researchers, will want to know the effect of alternative seedbed preparation approaches (conventional plowing, chiseling, zero tillage, etc.) on the various weed control strategies and he will, therefore, consult with the appropraite agronomy and/or agricultural engineering specialists. Cultivation is impossible in zero tillage. Leaving residues on the soil surface impairs the effectiveness of certain herbicides, hence may rule out non-plow systems on farms where certain weed species are prevalent. The plant pathologist enters the picture because certain plant diseases problems are accentuated by leaving residues of the preceeding crop of the same species on the surface, whereas others are not. For example, it is my understanding that yellow leaf blight of corn is dramatically worse almost to the row where corn residues are left on the surface. Northern leaf blight (Helminthosporium turcicum) is much less affected.

The entomologist becomes involved because corn borer is partially controlled by chopping corn stalks in the fall or plowing them under. Corn rootworm is greatly reduced by growing alternative crops in sequence rather than continuous corn.

von Rümker, Rosmarie

October 22, 1973

In answer to your question as to whether all of the pertinent variables are regularly incorporated into single **experiments**, the answer is no, because that would be impracticable if not impossible. A cogent reason for not combining all aspects into single experiments is that the problems to be studied do not all occur at the same place. The ever-present challenge to researchers is to combine into single experiments the minimum number of variables that must be tested in combination and then to test other combinations in other experiments so that that overall research input is most efficiently utilized. One cannot hope to duplicate all of the individual farm situations involving soil type, cropping sequence, particular weed, insect and disease problems, seedbed preparation preferences, date of planting, plant population, etc. When you combine a large number of variables into a single experiment you lose some capability to identify the contribution of each, hence while gaining insight into the interaction of multiple factors in the specific location, you lose capability to develop general principles from which to extrapolate the results to other locations. Furthermore, the experiment becomes unmanageably large. This introduces additional soil variability which is undesirable because it usually increases unexplainable variability which in turn requires greater differences for statistical significance.

In the final analysis, the individual farmer must assume considerable responsibility for fitting pieces together because pre-tailored packages of practices will always have to be too general to fit his particular system. Each farmer has certain likes and dislikes. Credit situations are often unique and are dynamic from year to year. As we have experienced recently the economic picture sometimes changes suddenly and without time to reprogram a preconceived package before a critical decision must be made. Supplies of seeds, fertilizers, and specific pesticides vary among localities and are sometimes subject to sudden changes.

To help farmers in developing well coordinated crop production systems the University of Illinois has developed a cadre of specialized crop production advisers consisting of County Extension Advisers who annually receive special training in all aspects of crop production by experts in soils, fertility, plant breeding, plant pathology, entomology, agricultural engineering, marketing etc. This program has been operational in total for at least five years and in part for about ten years.

Coordinated crop production - crop protection schools have been widely held at county and muticounty levels for fifteen years. The program is jointly planned and presented, usually on a two-day basis, by four to seven subject matter specialists from agronomy, plant pathology, entomology, engineering and economics. This type of educational meeting results in a substantial amount of intertwining of production practices both for and with farmers.

I am sending the Illinois Agronomy Handbook for 1973 which was jointly prepared by agronomists, entomologists, plant pathologists and horticulturists and the Proceedings of the Custom Spray Operators School which documents the multidisciplinary approach to practical problems.

I feel that there is close liaison among disciplines here at the University of Illinois and at Cornell where I was located for fifteen years. I believe a substantial shift has already taken place over the past twenty years and that it is accelerating especially in the area of environmental concerns. I have recently moved into a newly created position as Assistant Director of the Experiment Station with responsibility as Director of the Environmental Quality Council for the purpose of promoting coordinated activities within the College of Agriculture. Each of the Task Forces within the Council includes representatives from several departments, other colleges and outside agencies.

At the University level, the Institute for Environmental Studies was recently established to promote interdisciplinary research and teaching.

The Corn and Soybeans Study Team of the National Academy of Sciences Pesticide Study Committee will be making an in-dpeth analysis of pest control strategies in the cornbelt during the next six to eight months. It is a multidisciplinary team as is the parent Executive Committee on which I serve. The products of both the Study Team and Executive Committee are directed at some of the concerns involved in your study.

Sincerely,

Samuel R. Aldrich

Samuel R. Aldrich
Assistant Director

SRA:ph
enc.
cc: O. G. Bentley